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3. Taylor, G.I., 1932, Proc. R. Soc. (London) A, 138, 41.

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CORRIGENDA

Vol 1-2, p. 76: The authors of this article, part II of which appears in the present number, are affiliated to the Division of Plant Pathology, Agricultural Research Station, Rehovot, and not to the Hebrew University.

Vol 1-2, p. 103: Table III Results for Maximum Positive Deviation from Mean Value are, from left to right—6.3 5.8 5.8 6.4 7.0 4.3 3.0

AN INVESTIGATION INTO THE RHEOLOGICAL PROPERTIES OF BITUMEN

I. MAXWELL-BODY AND ELASTIC DISPERSIONS*

BY

M. REINER

Institute of Technology, Haifa

It is shown that while for infinitesimal elastic strain e , no difference in the rheological behaviour of sols and gels can be distinguished, the first represented by a structural formula of the type: $S=N-K=N-(H/N)$, the second by $G=N/M=N(H-N)$; this is not so when the strain is finite. In the latter case, the true viscous resistance of a prism of length l in extension is measured by $f = \dot{l}/l$, while the 'viscosity' due to Maxwellian relaxation of the stresses is measured by $\dot{e}$ which is equal to f only when the strain is measured in accordance with Hencky. The measure of the strain e , when finite, not being unequivocal; different flow curves will result from different measures of strain, even in pure extension. In simple shear, an elastic sol will exhibit flow curves similar to those in pure deformation, while an elastic gel will simulate variable viscosity. Rheological observations of large deformations of materials which may exist in the sol and gel state, such as bitumen, therefore supply information from which an insight into the structure of the material can be gained.

Preliminary Remarks. In the course of an investigation into the rheological properties of bitumen undertaken under the sponsorship of the Research Council of Israel, which forms a continuation of a research already reported upon¹, much time was lost in an attempt to interpret experimental results in accepted terms. It became clear that a revision is required of the fundamental concepts used in the theoretical evaluation of the observations^{**}. This revision was carried out and forms the present communication in which the investigation is described. Part II, which is to follow, will contain the observations, discussions and conclusions reached.

* Received April 1950.

** Addition at the time of correction: Compare also the discussion REINER-ROSCOE., 1950, Brit. J. Appl. Physics, 1, 332.

1. HISTORICAL INTRODUCTION

For nearly a century the theory of the viscosity of liquids was presented from the phenomenological point of view given by Stokes in the 1840's, in which (to use modern terminology) the tensor of stress is related linearly to the tensor of flow*. In this, Stokes followed the example of Newton who, in the "Principia," first defined viscosity as a "lack of slipperiness". When, however, earlier in the nineteenth century, Poisson first attempted to establish a dynamic theory of viscous liquids, he started out not from the notion of internal friction, but from notions of *elasticity*. He reasoned as follows:— Let us consider a "body" of liquid in equilibrium which we subject to a deformation. In order that the liquid may again attain a state of equilibrium a certain period of time is required, which differs for various kinds of liquids. The transition is characterized by a *deviation* of the pressure from isotropic or "hydrostatic" pressure. This deviation, which is caused by the deformation, *tends* to disappear, but actually disappears only when the state of equilibrium is completely re-established. — This notion of "relaxation" was taken up by Maxwell in the 1860's and it will be of interest to quote verbatim from his paper:—

"A distortion or strain of some kind, which we may call e , is produced in the body by displacement. A state of stress or elastic force which we may call p is excited. The relation between the stress and strain may be written $p = \epsilon e$, when ϵ is a coefficient of elasticity for that particular kind of strain (i.e. it is Young's modulus if p is a tension and e an extension caused by it and it is the modulus of rigidity in the case of shear.). In a solid body free from viscosity p will remain $= \epsilon e$ and $\dot{p} = \epsilon \dot{e}$ (using Newton's dot to denote derivatives in respect of time). If however, the body is viscous, p will not remain constant, but will tend to disappear at a rate depending on the value of p and on the nature of the body. If we suppose this rate to be proportional to p , the equation may be written

$$\dot{p} = \epsilon \dot{e} - p/\tau \quad (1.1)$$

which will indicate the actual phenomena in an empirical manner (i.e. only macroscopically descriptive, without regard to the microscopic mechanism underlying them). For if e be constant $p = \epsilon e e^{-t/\tau}$ showing that p gradually disappears; so that if the body is left to itself it gradually loses any internal stress. If $\dot{e}$ is constant ($=c$) — that is, if there is steady motion of the body, which continually increases the displacement,

$$p = \epsilon \tau c + C e^{-t/\tau} \quad (1.2)$$

* We are using the term "flow" for what is sometimes called "rate of deformation," as explained in Section 6 below.

showing that p tends to a constant value depending on the rate of displacement. The quantity $\epsilon \tau$, by which the rate of displacement must be multiplied to get the force, may be called the 'coefficient of viscosity'. It ($\epsilon \tau$) is the product of a coefficient of elasticity, ϵ , and a time, τ which may be called the time of relaxation of the elastic force. In mobile fluids τ is a very small fraction of a second and ϵ is not easily determined experimentally. In viscous solids τ may be several hours or days, and then ϵ is easily measured".

2. THE RHEOLOGICAL EQUATION OF THE MAXWELL-BODY

I have given this historical review here because Maxwell's idea of viscous flow did not find much recognition and was ultimately forgotten. It is characteristic that the vast "Handbuch der Physik" does not mention it at all. This was detrimental to further development. As long as Stokes' idea prevailed, a liquid was thought to be a kind of condensed gas. Only when it became obvious that, rheologically, the liquid is nearer to the solid than to the gas, was Maxwell's idea taken up. It was applied to *liquids*, but it is important to note that, in the passage quoted above, Maxwell speaks of "viscous solids". Before proceeding further we must warn the reader not to confound Maxwell's viscosity with the "solid viscosity" of Kelvin and Voigt which manifests itself in the lagging of otherwise perfect elasticity, causing delayed elasticity, and is characterized by a retardation-time τ_K . Rheologically speaking, Maxwell's body must be considered as a liquid, flowing, as it is supposed to do, under the *smallest* stress-difference, where flow is defined as a deformation in time which does not stop as long as the stress-difference subsists. Accordingly, Burgers² proposed for it a model consisting of an elastic spring and a dashpot coupled in series as shown in Fig. 1. The force taken by the spring is the same as that one taken up by the dashpot, while the rates of extension are additive. In a "structural formula", the model can be expressed as

$$M = N - H \quad (2.1)$$

where N (Newton) indicates the dashpot, H (Hooke) the spring and the horizontal dash — coupling in series.

Denoting Trouton's coefficient of viscous traction, the viscous analogy to Young's modulus, by λ , we accordingly have in extension

$$\dot{\epsilon} = \dot{p}/\epsilon + p/\lambda \quad (2.2)$$

which is identical with (1.1) for

$$\tau_M = \lambda/\epsilon \quad (2.3)$$

Fig. 1

Model of a Maxwell Body.
 ϵ modulus of elasticity of spring; λ coefficient of viscosity of dashpot; P , load. The model was built up from ordinary laboratory units connected by Mecano parts. The drum is driven by a clockwork motor. The test tube is filled with castor oil. An elongation-time diagram is registered on the drum.

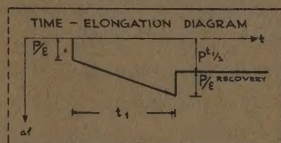
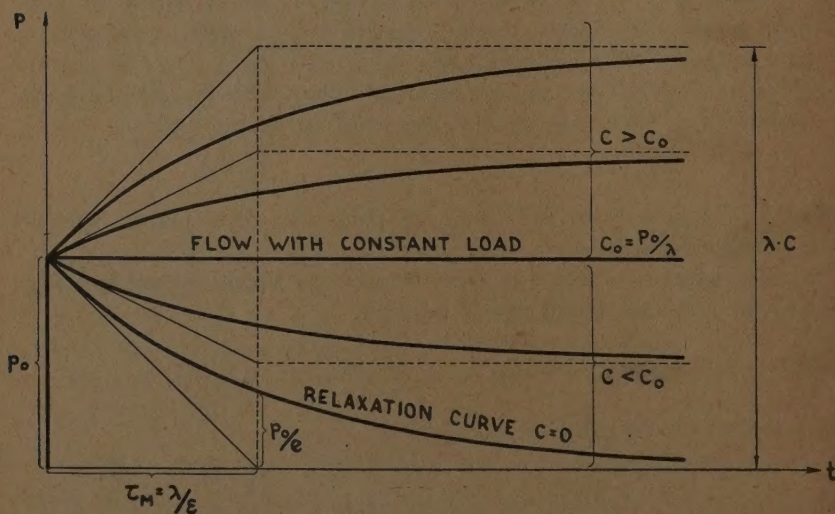


Fig. 2

Stress-time curves of a Maxwell-body for constant-strain velocity c
 ϵ Young's modulus; λ Trouton's coefficient;
 τ_M relaxation time; e basis of natural logarithm.



Equation (1.1) was integrated by Reiner³ (p. 91) with the result

$$p = e^{-t/\tau} \left(p_0 + \varepsilon \int_0^t \dot{e} e^{t/\tau} dt \right) \quad (2.4)$$

For constant extension-velocity $\dot{e} = c(\dot{e})$, the dependence of stress on time is shown in Fig. 2.

For $c(\dot{e}) = p_0/\lambda$ the stress is constant $= p_0$ and the material accordingly flows with constant deformation-velocity under constant stress as any Newtonian liquid. If $c=0$, i.e., if a constant deformation is maintained, the stress p decreases asymptotically to zero. This gives the relaxation curve

$$p = p_0 e^{-t/\tau} \quad (2.5)$$

If $c(\dot{e}) > p_0/\lambda$ the stress increases, if $c(\dot{e}) < p_0/\lambda$ it decreases, in both cases until a stress appropriate to $c(\dot{e})$, i.e. $= c(\dot{e}) \cdot \lambda$ is reached, when it remains constant. If on the contrary the stress increases at a constant rate, i.e. $\dot{p} = c(\dot{p})$ and therefore $p = c(\dot{p}) \cdot t$

$$e(t) = c(\dot{p})/\varepsilon \cdot (t + t^2/2\tau_m) = p(t)/\varepsilon \cdot (1 + t/2\tau_m) \quad (2.6)$$

As has been said before, the material of which (2.2) is the rheological equation is, rheologically speaking, a liquid, because a solution of the equation in which both stress p and deformation e are constant or $\dot{p}=0$ and $\dot{e}=0$, is only possible if $p=0$. In other words: if the stress is finite, there is a finite rate of deformation, or flow.

A Maxwell-body behaves in accordance with the magnitude of τ_m which constitutes its intrinsic time scale. Writing (2.2) in the forms

$$e = 1/\varepsilon \cdot (1 + t/\tau_m \cdot \int_0^t p dt) \quad (2.2.1)$$

$$p = \lambda \dot{e} + \dot{p} \tau_m \quad (2.2.2)$$

we see that if the duration of the experiment is very short ($t \ll \tau_m$), $e = p/\varepsilon$, and the material impresses as an elastic (Hookean) solid; while if the duration of the experiment is very long ($\tau_m \ll t$), $p = \lambda \dot{e}$, and the material impresses as a viscous (Newtonian) liquid; for example, concrete, the elastic modulus of which is of the order of magnitude of 10^{11} dyne cm^{-2} , while its coefficient of viscosity was calculated by Reiner⁴ (p. 242) as of the order of 10^{17} poises. Its time of relaxation is therefore of the order of 10^6 seconds. To loadings lasting hours or days it responds as an elastic solid and this makes it suitable as a structural material, but if one observes it for months or years,

flow is discernible, a flow so slow that it has been named *creep*. At the same time we can understand why Maxwell's idea received so little attention among physicists. Until quite recently, physicists very seldom dealt with materials such as concrete or asphalt and the like, which show creep. Maxwell had used his idea in order to derive a dynamic theory of gases, and for the relaxation time of air he calculated a value of 1.961×10^{-10} seconds. In homogeneous one-phase systems the time of relaxation is either very small, and then these are classed among the simple liquids, or very high, and then they are classed among the simple solids. Nobody has yet determined the (shape) elasticity of water, τ_M being too small, nor the creep viscosity of steel at room temperature, τ_M being too great.

3. ELASTIC SOLS

Maxwell's ideas were revived when dispersed systems with either small, but not too small τ , such as a 1.5% starch dispersion, or great but not too great τ , such as the concrete mentioned above, began to receive attention. Since then many "liquids" showing elasticity have been investigated, but the situation is very different with regard to materials of the first kind for which τ is small and those of the second kind for which it is large. What is behind the rheological behaviour of the first kind is actually not a "relaxation of elastic stresses" or gradual dissipation of the elastic potential energy. A coarse picture of the structure will show minute springs or other elastic bodies suspended in the solvent, e.g. water, which itself is not elastic. When the solvent is subjected to flow or continuous deformation, forces are exerted by the solvent upon the "springs" which are extended and to which they, in turn, resist elastically. The elasticity of the dispersed system accordingly resides in the *solute*: when the flow stops and the deformation does not continue the "springs" contract and the internal stresses of the whole system disappear. This takes time and simulates a sort of "relaxation" time. *In such a sol-system the whole of the stress is transmitted by the liquid phase to the solid phase, the external forces acting directly upon the liquid phase.* Because, however, the "springs" are suspended in the liquid phase, their elastic deformation cannot be instantaneous but is retarded by the viscous resistance of the liquid. The model of Fig. 1, therefore, does not correctly represent the flow phenomena and the spring must be coupled in parallel with a retarding dashpot, a combination which is the model of the Kelvin-Voigt body

$$K = H | N \quad (3.1)$$

the vertical dash indicating "coupling in parallel". The complex material

$$B_u = N - K = N - (H | N) \quad (3.2)$$

the model of which is shown in Fig. 3, may be named Burgers-body⁵.

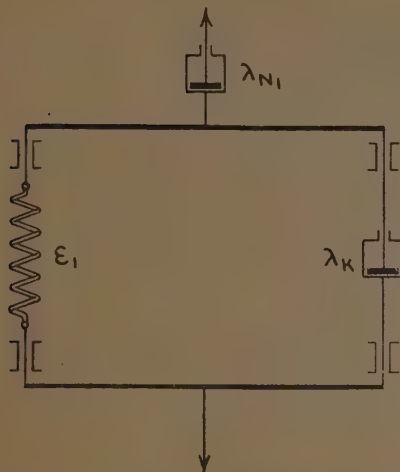


Fig. 3

Model of a Burgers-body consisting of a Newtonian dashpot coupled with a Kelvin-body $Bu = N - K = N - (H/N)$

Froehlich and Sack⁶ have calculated how a suspension of *elastic spheres* in a viscous liquid should behave rheologically as a first approximation. They found a rheological equation which, written in terms of rate of shear $\dot{e}_t$ and shearing traction p_t is

$$p_t + \tau_1 \dot{p}_t = \eta_E (\dot{e}_t + \tau_2 \ddot{e}_t) \quad (3.3)$$

where τ_1 and τ_2 are spoken of as "relaxation-times"* and η_E is Einstein's expression for the viscosity of a suspension of rigid spheres⁷. Let c_v be the volume concentration of the spheres, then Froehlich and Sack found

$$\left. \begin{aligned} \tau_1 &= 3\eta/2\gamma \cdot (1 + 5/3 \cdot c_v) \\ \tau_2 &= 3\eta/2\gamma \cdot (1 - 5/2 \cdot c_v) \\ \eta_E &= \eta (1 + 5/2 \cdot c_v) \end{aligned} \right\} \quad (3.4)$$

as long as the deformation of the spheres is small, η being the viscosity of the liquid phase and γ the modulus of rigidity of the spheres. If we assume the spheres to be rigid by putting $\gamma = \infty$ both τ disappear.

For very small elastic strains Reiner⁴ (p. 280) derived the following rheological equation

* That this nomenclature is not correct will presently be shown.

tion of the Bu-body in terms of one-dimensional traction and extension, without making any assumption about the micro-structure of the material.

$$\dot{e} = p \frac{\lambda_n + \lambda_k}{\lambda_n \lambda_k} - \frac{\epsilon}{\lambda_k} e^{-\epsilon/\lambda_k \cdot t} \left(e_{0k} + \frac{1}{\lambda_k} \int_0^t p e^{\epsilon/\lambda_k \cdot t} dt \right) \quad (3.5)$$

Introducing

$$\tau_k = \lambda_k / \epsilon \quad (3.6)$$

differentiating in respect of time and eliminating the second expression within the brackets in (3.5) we get

$$p + p \frac{\lambda_n + \lambda_k}{\lambda_k} \tau_k = \lambda_n (\dot{e} + \tau_k \ddot{e}) \quad (3.7)$$

In order to understand the rheological behaviour of the Bu-body and the meaning of the constants, let the prism be extended to some value e_0 and then be released at the time $t=0$, so that $p = \dot{p} = 0$. Equ. (3.7) is then reduced to a differential equation in e which on integration yields

$$e - e_\infty = (e_0 - e_\infty) e^{-t/\tau_k} \quad (3.8)$$

Th part $e_0 - e_\infty$ of the extension is recoverable and is therefore elastic. But in contradistinction to the Maxwell-body, the recovery is delayed with a retardation time τ_k . On the other hand, if we fix the extended prism so that $\dot{e} = \ddot{e} = 0$, we find that the stress relaxes in accordance with

$$p = p_0 e^{-\frac{\lambda_k}{\lambda_n + \lambda_k} \cdot \frac{t}{\tau_k}} \quad (3.9)$$

and the relaxation time is

$$\tau_{rel} = \frac{\lambda_n + \lambda_k}{\lambda_k} \tau_k \quad (3.10)$$

We can, therefore, write (3.7) as

$$p + \dot{p} \tau_{rel} = \lambda (\dot{e} + \tau_{rel} \ddot{e}) \quad (3.11)$$

which is the extensional form of (3.3) considering that in steady flow $\lambda = 3\eta$ (compare Reiner⁴ p. 185), where τ_{rel} is a time of relaxation and τ_{ret} a time of retardation. Equ. (3.11) is more general than (3.3) being independent of any special assumption about the structure of the material as implicit in (3.4) It can also be written as

$$\varepsilon(e + \tau_{ret} \dot{e}) = p + 1/\tau_{rel} \cdot \int p dt \quad (3.12)$$

in which form Jeffreys⁸ proposed it for the description of the rheological behaviour of the earth's crust.

4. ELASTIC GELS

Conditions are different in those systems which are dispersions of liquids in solids, or in other words, gels. Here *the external surface forces act directly upon the solid phase and the stress is transmitted by the solid to the liquid phase*. In these systems flow or creep is due to the relaxation of the elastic forces set up by the deformation of the solid phase. Here again the elastic response is retarded. An appropriate model is the one shown in Fig. 3, for which we write the structural formula

$$G = N | M = N | (H - N) \quad (4.1)$$

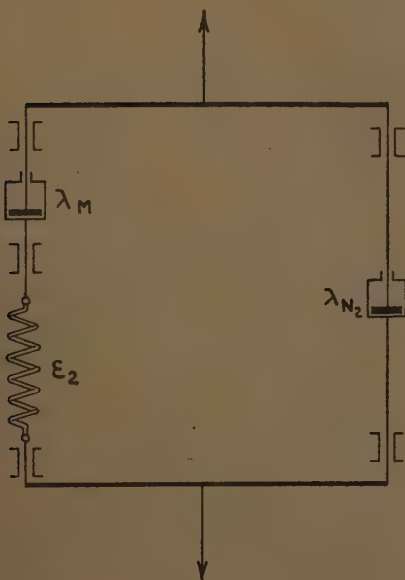


Fig. 4
Model of a gel consisting of a Newtonian dashpot coupled in parallel with a Maxwell-body.

Such a model was proposed by Poynting and Thomson^{9*} for the description of elastic after effects in glass fibres, and later by Lethersich¹⁰ for bitumen. A material corresponding to it might be referred to as bitumen-gel (G) or more general as Maxwell-gel. Reiner⁴ (p. 286) derived its rheological equation in extension in the form

$$p = \lambda_n \dot{e} + e^{-\epsilon/\lambda_m \cdot t} (p_{0m} + \epsilon \int_0^t \dot{e} e^{\epsilon/\lambda_m \cdot t} dt) \quad (4.2)$$

As before, we introduce

$$\tau_m = \lambda_m / \epsilon \quad (4.3)$$

differentiate in respect of time and, eliminating the expression in the brackets we get

$$p + \dot{p} \tau_m = (\lambda_n + \lambda_m) \left(\dot{e} + \frac{\lambda_n}{\lambda_n + \lambda_m} \cdot \tau_m \ddot{e} \right) \quad (4.4)$$

Again extending a prism by e_0 and keeping it strained $\dot{e} = \ddot{e} = 0$ we find that the stress relaxes with τ_m as time of relaxation. On the other hand if we release the extended prism so that $p = \dot{p} = 0$ we find

$$e - e_\infty = (e_0 - e_\infty) e^{-\frac{\lambda_n + \lambda_m}{\lambda_n} \cdot \frac{t}{\tau_m}} \quad (4.5)$$

and we see that the elasticity is delayed with

$$\tau_{ret} = \frac{\lambda_n}{\lambda_n + \lambda_m} \cdot \tau_m \quad (4.6)$$

as retardation time. We again arrive at a rheological equation of the form (3.11), with however, a different structural interpretation of the parameters. Among the materials behaving in accordance with the model are concrete, (which we mentioned in Section 2 as an example of the Maxwell-body but which in a second approximation would be a Maxwell-gel) and glass, which the physico-chemist refers to as an undercooled liquid, but which rheologically may be considered a gel, its time of relaxation being of the order of 10^7 seconds or about ten times that of concrete, which is, therefore, more "fluid" than glass.

In a third approximation we would have to take account of an instantaneous acous-

* This apparently was the first mechanical model consisting of a spring and a "viscous damper". Their model looks slightly different from, but is essentially, the same as, that shown in Fig. 4.

tical elasticity such as concrete, glass and some bitumens show, by adding a spring element in series. The source for an acoustical elasticity can be two-fold. First, every material, solid and liquid alike, shows volume-elasticity which is instantaneous, and in axial extension under the traction p its isotropic component $p/3$ must cause a volume-dilatation e_v which is

$$e_v = p/3\kappa \quad (4.7)$$

where κ is the bulk-modulus and from which in turn an extension

$$e_l = e_v/3 = p/9\kappa \quad (4.8)$$

results. This is the instantaneous elastic extension considered by Lethersich¹⁰, and on these grounds we should add a spring in series also to the Bu-body, Equ. (3.2)*.

κ however, is comparatively very great and e_v will be correspondingly small and this, therefore, cannot be the only cause of the instantaneous extension of concrete which is fairly great. The second cause lies in the fact that in many gels the liquid phase will not entirely fill the voids in the solid structure of the gel and leaves voids filled with air or vapour. Part of the deformation of the gel will therefore not be damped by the viscous resistance of the liquid phase and will proceed with acoustic speed. This will be the case with concrete, asphalt and the like.

5. BITUMEN SOLS AND GELS

In accordance, therefore, with the magnitude of the relaxation time τ_{rel} we may distinguish, on one hand, the simple viscous (Newtonian) liquid which is entirely devoid of elasticity of shape for which $\tau_{rel} \rightarrow 0$ (the Stokes liquid being a special case for constant volume), and, on the other hand, the simple elastic (Hookean) solid for which $\tau_{rel} \rightarrow \infty$. These theoretical extremes become of practical significance when it is kept in mind that the span of human life is of the order of 10^9 seconds and that, in accordance with certain theories, a limited time of the order of 10^{14} seconds has elapsed since the "creation" of the universe—a timespan which for man is "infinite". Even the rheologist, therefore, should not say *παρὰ ὅτι* and when Preston¹² calculates for some glasses at room temperature a viscosity of 10^{60} to 10^{70} poises, (which, considering that the elastic modulus of glass is of the order of 10^{12} bars, would imply a relaxation time of, say, 10^{50} seconds), he is correct in saying that such a viscosity is without meaning. On this view both extreme materials with non-measurable relaxation times have real existence and between them we would have the Maxwell-body with finite τ_{rel} . But it must be conceded that the materials which may, as the first approximation, be

* Compare also LEE and MARKWICK¹¹

considered as Maxwell-bodies, do not entirely conform to the picture which Poisson and Maxwell had in mind. They are *dispersed systems*, either sols, with relaxation time of the order of magnitude of 10^3 seconds or less; or gels where τ_{rel} is of the order of 10^6 seconds or more; and a region of transition where both states may exist side by side. In contradistinction to what is assumed for the Maxwell-body, their elasticity is not instantaneous as assumed by Poisson and Maxwell, *but delayed*. A striking example of a material which exists in both states is bitumen. Pfeifer and Saal¹³ have shown that, rheologically speaking, there are two distinct kinds of bitumen. Bitumen consists of a dispersion of micelles in heavy viscous oil, the latter named the "maltene" fraction. The micelles are formed by the "asphaltene" fraction, which consists of high-molecular hydrocarbons, adsorbing on their surface and absorbing in the interior maltenes. This part of the maltenes is often referred to as the "resins"*. When the entire system contains sufficient constituents for the formation of the outer resins, the asphaltenes are fully peptized and able to move through the bitumen as freely as the viscosity of the oily maltenes permits. Such systems are *sols* showing viscous flow with intramicellar elasticity (compare Fig. 5).

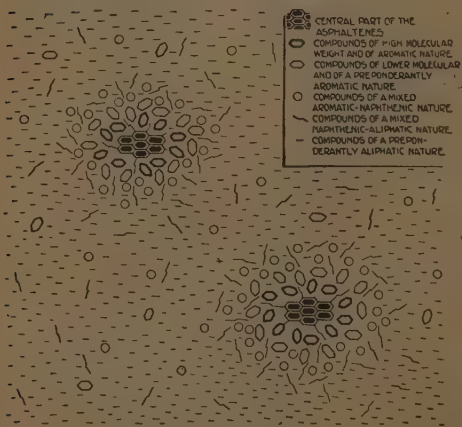


Fig. 5. Bitumen-Sol

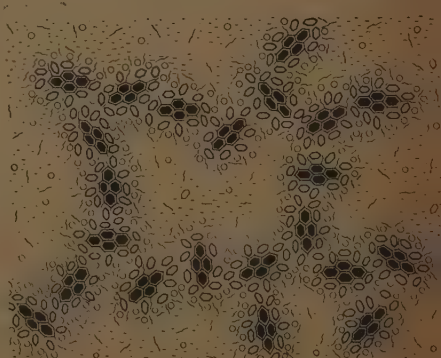


Fig. 6. Bitumen-Gel

Pfeiffer and Saal's schematic representation.
Reproduced with Dr. Saal's kind permission.

If, however, there is a shortage of resins, part of the forces causing the formation of the micelles are not compensated by adsorption, and the micelles will attract each other. Thus a *gel-structure* is formed which Pfeiffer und Saal describe as irregular open packing, the spaces of which are filled by the viscous liquid (compare Fig. 6).

* In another terminology the oily dispersion medium is called "petrolenes" and the term "maltenes" is applied to the resins only.

In view of the fact that the intermicellar forces will be subject to relaxation, this gel must be considered a Maxwell-body. Because, however, of the presence of viscous maltenes, both between and within the micelles, the elasticity of the micelles in the case of the sol or of the whole gel-structure cannot work "instantaneously" at acoustic speed, but will be delayed by the Kelvin-Voigt kind of solid viscosity.

The problem of the present investigation is whether we can *by means of rheological measurements gain any insight into the structure of some definite sample of bitumen?* In other words: can we decide whether it belongs to the sol- or gel-type? The method to be applied has been named by Reiner⁴ (pp 70—93) rheological analysis and applied with some measure of success by Reiner and Schoenfeld-Reiner¹⁴ to rubber-toluene sols. At first sight the prospects do not look favourable. Both bodies, the Bu- given by the structural formula (3.2) and the PTh- given by the structural formula (4.1), are reducible to the same rheological equation (3.11). When their specific rheological equations (3.5) and (4.2) are translated into graphs, they fall on the same curve (compare Fig. 7) and are thus indistinguishable. On second thoughts, however, it is found that the prospects are better.

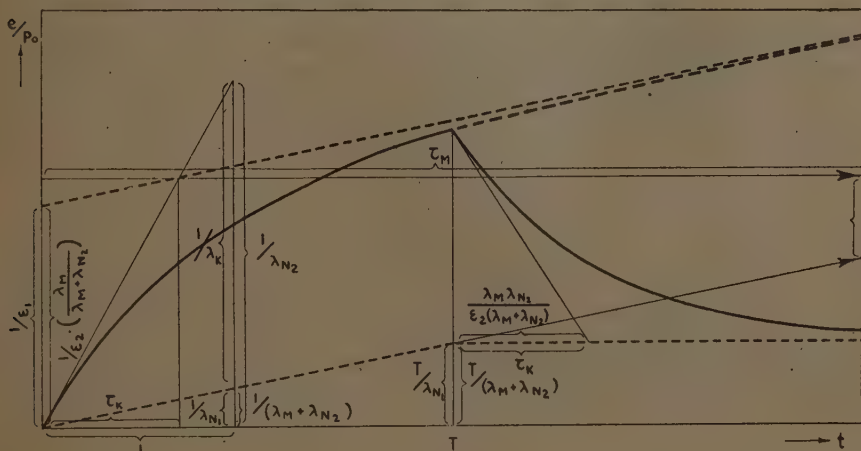


Fig. 7

Strains per unit stress versus time curves for the Bu and G bodies.

ϵ Young's modulus; λ Trouton's coefficient; "M" of Maxwell-body; "K" of Kelvin-body; "N" of Newtonian liquid; e extension; P_0 constant traction; t time; T period of leading; τ_M relaxation time; τ_K retardation time.

6. TERMINOLOGICAL DIGRESSION

It will presently be shown that the identical rheological behaviour of the elastic sol and the gel type results from the fact that only infinitesimal elastic strains have been

considered. The situation changes radically when one considers finite strains. This, however, requires a more discriminative terminology and notation.

We shall denote by D (in tensor form D_{rs}) the deformation of a body irrespective of whether it is elastic or the result of viscous flow. By e (e_{rs}) we shall denote that part of it which is recoverable and name it "strain". (Strain, therefore, is always elastic). We shall denote by flow, f (f_{rs}) the tensor derived from the velocity vector (v_r) in the same manner as the infinitesimal strain is derived from the displacement vector (u_r). We shall use Newton's dot to denote time-derivatives. Now it should be kept in mind that while

$$v_r = \dot{u}_r \quad (6.1)$$

the tensor of flow is generally *not* the time-derivative of the tensor of deformation or the strain. This is only the case when strain or deformation is *infinitesimal* and only in this case is it correct to use the term "rate of deformation" or "rate of strain" for what we have here named "flow". These considerations are still further complicated by the fact that the terms "deformation" and "strain" are not unequivocally defined. This will become obvious when we consider linear extension under one-dimensional traction. Let the material be shaped as a prism, one end of which is fixed at the point $x=0$ while the other end, at $x=l$, moves with the velocity v_l . Then the flow dv/dx will be homogeneous and be simply v/x or

$$f = v_l/l = (dl/dt)/l \quad (6.2)$$

The elongation is

$$\Delta l = l - l_0 \quad (6.3)$$

In the case where the strain (=elongation per unit length) is measured by the Cauchy measure

$$e^c = \Delta l/l_0 = l/l_0 - 1 \quad (6.4)$$

$$e^c = l/l_0 - 1 \quad (6.5)$$

and only when the elongation is so small that l can be replaced by l_0 , is e^c equal to f . Similarly when the Swainger-measure is used

$$e^s = \Delta l/l = 1 - l_0/l \quad (6.6)$$

we have

$$\dot{e}^s = l_0 \dot{l} / l^2 \quad (6.7)$$

which also is reduced to f only if l_0 can be replaced by l .

On the other hand, if we define the strain by the Hencky measure

$$e^H = \ln(l/l_0) \quad (6.8)$$

we find

$$\dot{e}^H = \dot{l}/l = f \quad (6.9)$$

for finite strain and this is the great advantage of the Hencky measure. It should, however, be kept in mind that relation (6.9) is only valid in *pure* extension i.e. when there is no rotation of the principal axes.

In the general three-dimensional case there is no manner of defining e_{T_3} so that f_{T_3} should be equal to $\dot{e}_{T_3}$

As mentioned above, we shall use the symbol e only for the recoverable part of the deformation, while deformation, if the result of viscous flow, will be D^C , D^S or D^H etc.

In order to appreciate the difference between the various measures of deformation or strain, let us consider the case when the length l_0 is extended to $l=2l_0$. In this case e^C is 100%, e^s 50%, all other measures giving figures lying between these extremes.

7. THE RHEOLOGICAL EQUATIONS IN CASES OF FINITE STRAIN

7.1 With the terminology and notation of the preceding section in mind we can now say that for the Maxwell-body, where continuous deformation does not result from viscous flow but from a relaxation of stress, we have to consider a strain e measured in some manner and a rate of strain $=\dot{e}$, and Equ.(1.1) is applicable whatever the magnitude of the strain. We accordingly have for the Maxwell-body, for finite strain, as before,

$$\dot{p} = \varepsilon \dot{e} - p / \tau_m \quad (7.1)$$

and

$$p = e^{-t/\tau_m} \left(p_0 + \varepsilon \int_0^t \dot{e} e^{t/\tau_m} dt \right) \quad (7.2)$$

7.2 In the Kelvin-Voigt-body, on the other hand, the resistance to the appearance of the strain is a true viscous resistance and we have (compare Reiner⁴ p. 269)

$$p = \varepsilon \dot{e} + \lambda f \quad (7.3)$$

Integration is only possible after we assume a definite measure of strain. For instance:

(i) When the strain is measured by e^c , Equ. (7.3) yields

$$l + \frac{\varepsilon}{\lambda l_0} l^2 - \frac{\varepsilon + p}{\lambda} l = 0 \quad (7.4)$$

For constant traction

$$p = p_0 = \alpha \varepsilon \quad (7.5)$$

the solution is

$$l/l_0 = (1 + \alpha) / (1 + \alpha e^{-[(1 + \alpha)/\tau_k \cdot t]}) \quad (7.6)$$

where

$$\tau_k = \lambda / \varepsilon \quad (7.7)$$

(ii) When the strain is measured by e^s Equ. (7.3) becomes

$$l + \frac{1 - \alpha}{\tau_k} \cdot l - l_0 = 0 \quad (7.8)$$

the solution of which, for constant traction, is

$$l/l_0 = (1 - \alpha e^{-(1 - \alpha)/\tau_k \cdot t}) / (1 - \alpha) \quad (7.9)$$

7.3 The rheological equation of the Bu-body can now be found by adding to the rate of deformation of the Kelvin-Voigt-body that due to the true viscosity λ_N of the dashpot coupled in series. For constant tractions the lengths are also additive and we have the case (i)

$$l = \alpha \frac{\varepsilon}{\lambda_N} t + (1 + \alpha) l_0 / (1 + \alpha e^{-(1 + \alpha)/\tau_k \cdot t}) \quad (7.10)$$

while in the second case

$$l = \alpha \frac{\varepsilon}{\lambda_N} t + l_0 (1 - \alpha e^{-[(1 - \alpha)/\tau_k \cdot t]}) / (1 - \alpha) \quad (7.11)$$

7.4 The rheological equation of the G-body or Maxwell-gel on the other hand can be found by adding to the traction of the Maxwell-body, Equ. (7.2), the viscous resistance of a dashpot λ_N coupled with it in parallel or

$$p = e^{-t/\tau_m} (p_{om} + \varepsilon \int_0^t \dot{e} e^{t/\tau_m} dt) + \lambda_N \dot{f} \quad (7.12)$$

which should be compared with Equ. (7.2).

With a similar procedure we find

$$\rho + \dot{\rho} \tau_m = \lambda_n (\dot{f} + \tau_m \ddot{f}) + \tau_m \epsilon \dot{\epsilon} \quad (7.13)$$

which can only be integrated after we assume a definite measure for ϵ .

From these considerations it follows that when the strain is finite the Bu- and PTh-bodies will exhibit very different rheological behaviour so that rheological observations can be used to decide whether some material, e.g., bitumen, is a sol or a gel-dispersion.

8. SHEAR

The different rheological behaviour is still more conspicuous when the material is *sheared*. In the one-dimensional extension, which goes hand in hand with lateral contractions, the principal axes of deformation are *not rotated*, while in simple shear they are rotated. It will presently be shown that when the axes are rotated, the rheological behaviour of a gel is entirely different from that of a sol.

To make this understood, we must discuss, at least cursorily, the kinematics of simple shear. Let us consider a material sheared between two rigid platens as shown in Fig. 8. A circular section is thus converted into an ellipse, and there is also an ellipse which is converted into a circle. Plane geometry teaches us how to find the axes of the ellipse when the shear is given. The geometrical construction is indicated in the figure. It will be seen that there are two diameters in the circle, normal to each other, which are converted into the axes of the ellipse, and *vice versa*. It will also be seen that, if the shear is infinitesimal, *these two directions make angles of 45° with the direction of displacement* x , and that they are infinitesimally rotated from the position in the circle to the position in the ellipse. If the shear is finite, the slopes of the axes are rotated by a finite amount α which increases as the shear increases. Now the point to be kept in mind is that we cannot measure the stresses in the interior of the sheared material. We can only measure the external forces acting upon the two rigid platens between which the material is sheared. These will be different for different materials. If the material is viscous and elastic at the same time, that *same* external force will act upon both the viscous and elastic elements.

Let us consider first a simple viscous liquid. In this case the stress is proportional to the flow f . The flow is derived from the velocity gradient in a manner similar to that used in Equ. (6.2) for the case of simple extension. In simple shear, where the velocity is in the direction of x while the gradient has the direction of y , we have

$$f = v/D \quad (8.1)$$

where V is the velocity of the moving platen and D the distance of both platens. Now, by definition, the velocity is an *infinitesimal* increment of displacement du in an infinitesimal increment of time dt , or $v=du/dt$. Therefore *the principal axes of the flow-deformation are always inclined at 45° against the direction of the laminar displacement*. The internal stresses are tension in the direction of one principal axis (i), compression in the other (j), (apart from a hydrostatic pressure) and the external force is tangential in the direction x .

9. SOL IN SHEAR

Now let the material be a suspension of minute elastic particles in a simple viscous liquid.

The external forces will act through the platens upon the liquid; will cause the liquid to be deformed continuously or, in other words, to flow; this will produce in the liquid internal stresses with principal stresses of tension and compression at angles of 45° with the direction of displacement; these internal stresses will act upon the particles in the same directions and will produce in the particles co-axial stresses. The whole system will behave as a Bu-body but its *kinematics* will not be different from the kinematics of a Newtonian liquid. It should be mentioned that it does not make any essential difference whether the suspended material is nearly rigid as, for instance, minute steel balls would be, or highly elastic as small rubber particles would be: in the first case an elasticity of the liquid suspension would not be noticeable; in the second case it would manifest itself in the manner described in Section 3 above.

10. ELASTIC SOLID IN SHEAR

The case is different when the material sheared between the platens is an elastic solid. Under the action of tangential forces transmitted through the platens, the material will be deformed to a certain extent and then will not change, with the internal stresses being tension in one principal direction, compression in the other, and the external tangential force in the direction x . Let us assume for the sake of simplicity that the material obeys the simple Hooke-law. In this case the stress is proportional to the strain.* If the material is, say, steel, where the strain in the elastic range is infinitesimal, the principal axes are, as we have seen, inclined at 45° against the direction of the displacement, exactly as in the case of the simple viscous liquid. The stress due to infinitesimal elastic strain is accordingly *co-axial* with the stress due to viscous resistance. Therefore, if one would observe the creep of steel in simple shear, this system, while constituting a Maxwell-body, would not behave differently from an elastic sol, the elastic deformation of steel being infinitesimal; and while creeping steel ac-

* It should be kept in mind that in simple shear the volume, even of a compressible material, does not change.

tually flows, both the flow and the strain (the latter defined as the *recoverable* part of the deformation) are co-axial. If the velocity V of the moving platen is kept constant, the stress would gradually increase until it reaches such magnitude that it relaxes at the same rate as it is being built up through straining, exactly in the same way as shown in Fig. 2 for extension replacing the Young modulus ϵ by the shear modulus γ and Trouton's coefficient λ by the ordinary shear coefficient of viscosity η .

The situation is entirely different when the material is *highly deformable* (we may think of rubber, forgetting that rubber does not obey Hooke's law). Now, when the deformation starts, and the strain is still infinitesimal, the principal axes are inclined at 45° ; but as the deformation proceeds the stresses grow, but at the same time the principal axes of tension and compression are rotated as shown in Fig. 8. This rotation of the principal stresses reduces the tangential reaction of the material to the platens. Therefore, as shear is increased, the tangential force exerted by the platens is not required to increase in the same measure: the material becomes in a certain way *softer*.

11. MAXWELL-GEL IN SHEAR

What now will happen if the material is a highly elastic Maxwell-gel, as e.g., blown bitumen? The external tangential force applied upon the platen must balance both the viscous and the elastic resistance of the gel, which also mutually balance each other. When the deformation proceeds at a certain rate, this force again increases in the same manner as shown in Fig. 2 until the relaxation balances the increase of stress. Then (theoretically after infinite time, but in practice quite soon) the external force is constant. But now in contradistinction to the case described in Section 10 above, the principal axes are *not* inclined at 45° ; the inclination of the tension-axis is *less*. When the velocity of deformation is greater, equilibrium will be reached at a higher stress, but because the tension becomes still "flatter", the stress will be comparatively less. To sum up: *when a highly elastic Maxwell-gel is subjected to shear, and the viscous resistance is determined when a state of equilibrium is reached, the behaviour of the material will be such as to simulate a decrease of viscosity with increasing rate of shear, even if the viscosity should actually be constant*. This will not be the case when the material is a sol.

12. VARIABLE VISCOSITY

The difference in behaviour of a gel and a sol is accordingly connected with the phenomenon of "variable" viscosity. The latter has been known for nearly half a century, but theoretical investigations do not go back more than about 25 years, when the present author coined the term "non-Newtonian" behaviour for what Wo. Ostwald

had called "structural" viscosity. It should be pointed out that at that time Weissenberg had already assumed that the effect was due to an elasticity of the liquid which in shear would simulate a variable viscosity. Burgers¹⁵ has more recently developed the theory in a paper the title of which is as much as an abstract. He calls his paper "Non-linear relations between viscous stresses and instantaneous rate of deformation as a consequence of slow relaxation". In the present paper it has been shown that such non-linear relation (non-Newtonian behaviour) will occur in a Maxwell-gel, where the external forces are transmitted to the material through the solid phase; but not in a sol, where the external forces are transmitted to the material through the liquid phase. With this development the reality of "structural viscosity" may be questioned in a Maxwell-gel. The viscosity of such materials is measured in shear either through a tube or between concentric cylinders, and far-reaching conclusions are sometimes drawn from a supposed variability of the viscosity. In both these instruments, however, the material is simply sheared, and therefore subjected to rotation. A decision whether the viscosity is variable or not can only be arrived at from experiments in *pure* deformation, i.e. in simple viscous *extension*. The application of this latter method is seldom possible. Fortunately we have in blown bitumen a material which can be observed by both methods.

An experimental investigation is now being carried out in which blown bitumen is subjected simultaneously to simple extension in an apparatus described by Reiner¹, and to shear in a rotational viscometer described by Lee¹⁶. The blown bitumen is known to be "non-Newtonian". It is hoped that by this investigation it will be possible to decide how much "reality" there is behind this phenomenon, and to distinguish between actually variable viscosity and an apparent variability due to high elasticity of the material.

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THE CHEMICAL COMPOSITION OF FODDER PLANTS IN ISRAEL *

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A summary is given hereunder of research on the systematic investigation of the most important Israel fodder plants. Reliable average results can only be obtained by examining a sufficiently large number of plants cultivated under different growth conditions and in different regions of this country. The influence of the different stages of growth of fodder plants on their chemical composition was investigated. Data obtained in this manner are essential for making the most advantageous use of plants for feeding purposes. Lack of proper estimation of the fodder value has led to widespread wastage, especially of proteins.

This work was carried out during the years 1947-1950. The following plants were examined :

Alexandrian clover misquavi (*Trifolium alexandrinum misquavi*)

Alexandrian clover fahli (*Trifolium alexandrinum Fahli*)

Horse beans (*Vicia faba*)

Field peas (*Pisum arvense*)

Cyprian vetch (*Lathyrus ochrus*)

Oat fodder (*Avena sativa*)

Lucerne (*Medicago sativa*)

Green maize (*Zea Mays*)

Wintersome (*Sorghum sp*)

Sunflower (*Helianthus annuus*)

Cow peas (*Vigna sinensis*)

Paspalum dilatatum

Rhodes grass (*Chloris Gayana*)

Mangels (*Beta vulgaris*)

Pumpkins (*Curcubito pepo*)

Melons

360 samples of those plants were collected in the following settlements in different parts of the country.

Southern district. Givath-Brenner, Na'am, Hulda, Negba, Gat.

* Received April 1951.

Coastal Plain : Ain Hahoresb, Givath Haim, Ma'abarothe, Mishmar Hasharon, Ramath-Hacowesh.

Surroundings of Haifa : Ain Hamifraz, Kfar Masarik, Ramat-Yohanan.

Western Israel Valley : Ginegar, Sarid, Gvath, Mizra.

Eastern Israel Valley : Merhavia, Beth-Hashita, Ain-Harod, BethAlpha, Kfar Yeheskel.

Jordan Valley : Maoz Haim, Afikim, Sdeh-Elijahu, Dagania A.

In all plant samples the contents of water, protein, fat, ash, crude fibre, calcium and phosphorus were analytically determined. The average results of 4-8 samples of each plant taken in different settlements are given in table 1. In order to estimate the nutritive value of the different plants, their contents of digestible crude protein and of "Fodder units" were calculated. For these calculations use was made of the average analytical results and the coefficients of digestibility, which were previously determined in this laboratory by experiments with sheep¹, we calculated the values of fodder units on the basis of the percents of digestible crude protein and not of that of digestible pure protein as prescribed by Hansson. On the other hand we renounced the multiplication of the crude protein with the factor 1.43 and therefore we arrived at the same values of fodder-units as by Hansson's original method.

ALEXANDRIAN CLOVER MISQUAVI : Samples of clover, cultivated with irrigation were taken for analysis from six different cuts between November and May. The comparison of the dry matter content of six different cuts shows that the third cut contains the smallest amount of dry matter. The dry matter content of clover-cut at the same stage of growing increases considerably with progressing season (from winter to spring — from 9.1% to 17.7%). The same fluctuations were found in the nutritive value of the different cuts. 100 kg of clover from the first cut furnish 8.7 fodder units, of the third cut 7.2 fodder units and of the last cut in June even 13.7 fodder units. The increase of crude fiber with advancing cut (from — 21% to 27% of the dry matter) and the decrease in the ash content (from 19% to 11% of the dry matter) is noteworthy and very considerable. At the end of the season the clover is usually cut as soon as it blooms; the results of our analysis showed no difference in the chemical composition of the dry matter of the clover, which was cut 3 or 6 weeks after the preceding cut. Therefore earlier cutting of the clover cultivated in May or June is not advantageous and there is no justification for the earlier cutting of the clover at the end of the season and the consequent loss of a part of the yield.

Clover cultivated without irrigation, which gives only 3 cuts instead of six with irrigation, is richer in dry matter, but also in crude fiber and no practical difference was found in the nutritive value of clover cultivated simultaneously with or without irrigation.

1.) See A. Bondi and H. Meyer, Chemical composition and digestibility of Palestinian cattle fodder. Bulletin 27, Agricultural Research Station, Rehovot 1940 and Agricultural calendar.

ALEXANDER CLOVER FAHLI : Fahli clover which gives only one cut, is cultivated without irrigation and serves chiefly for hay-curing. The chemical composition and dry matter contents of fahli clover are very similar to those of clover Musquavi cut simultaneously and of vetch-oats mixture, the crop most used for hay-curing in this country.

HORSE BEANS, FIELD PEAS AND CYPRIAN VETCH : Samples of these plants were taken in January and March, and cut at two different stages of growth; very young and in the beginning of the bloom. The analytical results show that the amount of dry matter increases considerably during growth and also with progressing season. These three plants do not differ with regard to their nutritive value, which rises with progressing season and with the increasing age of the plants. Their nutritive value is also very similar to that of clover cut simultaneously and at a comparable age. Horse beans, field peas, Cyprian vetch and Alexandrian clover are also very similar from the nutritional point of view.

OATS are almost the sole winter crop which is a gramineous plant and therefore it seems very suitable to balance the protein rich rations given to cattle in the winter months. But the nutritive value of oats is not satisfying and their yield is very low. These circumstances do not promote the cultivation of oats as a fodder crop. Dry matter content of this crop increases with progress of season and age of the plants.

LUCERNE : Samples of lucerne cut in different stages of development show the very great influence of the age of this plant on dry matter content and chemical composition. The considerable increase of the dry matter content during growth is accompanied, however, by a decrease in protein. But lucerne cultivated at different seasons, and cut in the same stage of growth does not show any significant difference in dry matter content or in chemical composition. Lucerne as a perennial crop differs from the legumes grown only in winter in the independence of its chemical composition from the growing season. Lucerne is a very nutritive fodder plant and supplies very great amounts of protein, fodder-units and minerals.

Comparison of the chemical composition of lucerne as of the other crops grown in different parts of the country does not show any remarkable influence of the climatic conditions on the composition of the plants. The only exception seems to be the calcium content of lucerne which is higher in that grown in the Jordan valley.

GREEN MAIZE : has been examined with special consideration of the differences between maize cultivated on irrigated and on non-irrigated soils. Maize grown on unirrigated soil is richer in dry matter content than the same plant cultivated on irrigated land. A considerable increase in dry matter content could be observed in both cases during advance of growth. According to the analytical results the composition of the dry matter will not be influenced by the age of the plants, season of cultivation or irrigation. The greatest yield of nutrients is obtained by harvesting the green maize

when the kernels reach the glazing stage. This forage when cut in short lengths, is consumed by stock with little waste.

WINTERSOME has been recommended during the last years as a substitute for green maize owing to its more extended growing season. A certain disadvantage of this plant lies in its crude fibre content which is considerably higher than that of green maize. The lignification of wintersome reaches higher dimensions and consequently it seems advisable not to cut it too late. Indeed Wintersome supplies larger amounts of nutrients than green maize cut at a comparable stage of development, but in consequence of the recorded disadvantages its cultivation seems mainly advisable after the end of the growing period of green maize.

SUN-FLOWER : Samples of sunflower which were cultivated with and without irrigation were taken in two different stages of growth, during budding and at the beginning of bloom. Sunflower cultivated without irrigation contains more dry matter and also protein than sunflower grown on irrigated soil. The dry matter content rises during the growth of this crop. Sunflower contains less nutrients than other summer crops such as green maize or Wintersome and therefore sunflowers are a crop suitable for cultivation in spring before the beginning of the growth of the other summer plants.

COW-PEAS : Samples of cowpeas were taken during the whole summer at two different stages of growth, at the beginning of bloom and at the stage of podformation. The fluctuations in the dry matter content and in the chemical composition of the different samples were insignificant. No increase in the dry matter content and no decrease in the protein content were found during the growth of the cowpeas, facts which can be ascribed to the formation of masses of young leaves as this crop develops. The maximum yields of dry matter and of nutrients are obtained at full bloom. Cowpeas yield the same amount of nutrients as green maize or wintersome, but cowpeas as a legume possesses a considerably higher protein content than other summer plants.

PASPALUM AND RHODES GRASS are usually sown together and sometimes lucerne is sown on the same plots. The plants grown in this manner are normally used for pasture purposes. Samples for analysis were taken during the summer months 2-4 weeks after grazing, and in November 6 weeks after grazing owing to the slower growing of the plants in autumn. Our analyses show that both Paspalum and Rhodes grass possess the same high fodder value. The chemical composition of Rhodes and Paspalum is more favourable than that of other pasture plants used abroad because of their higher protein content which is larger than that of all other nonleguminous plants examined in this work.

MANGELS (*Beta vulgaris*) : Samples of four different species of mangels were analyzed, viz.—: Eckendorfer, Mammut, Golden Tancred and Sludstrup. Mangels of

the latter three species contain greater amounts of dry matter and sugar than Ecken-dorfer, the most common species of mangels in this country. The feeding value of mangels does not fall below that of green forage plants such as sunflower, cow peas or young green maize. Mangels are a feed very rich in high digestible carbohydrates and mangels are good to balance the protein rich rations usual in this country. The calcium and phosphorous contents of mangels are very low.

PUMPKINS are cultivated without, or with but little irrigation during the whole growing period. Pumpkins belong together with mangels to the feeding stuffs rich in carbohydrates and poor in protein and minerals.

MELONS which are cultivated without any irrigation, are poorer in dry matter than mangels and pumpkins. The composition of the dry matter contained in these three feeding stuffs is very similar. The higher protein content found in melons is caused by the presence of seeds.

SUMMARY

The winter legumes such as Alexandrian clover musquavi, horse beans, field peas and Cyprian vetch are very similar in their nutritive properties. Dry matter content and nutritive value of these plants increase considerably with progressing season and during their growth. Green oats, which are almost the sole winter growing gramineous plant, have a small dry matter content and are of inferior nutritive value. Lucerne, a perennial leguminous plant, which supplies very great amounts of nutrients, especially proteins, is independent in its dry matter content and chemical composition from the growing season, but its composition is considerably influenced by its stage of growth.

Paspalum and Rhodes grass, the essential components of the irrigated pasture, possess a very high fodder value.

Our analytical results enable a determination of the best cutting time which assures the highest yields of nutritive matter. Therefore we recommend postponing the cutting time of the following crops—: horse beans, field peas, Cyprian vetch, sunflower, cowpeas and green maize, thereby, gaining considerable amounts of dry matter and nutrients. On the contrary, the prolongation of the growing period of lucerne and of wintersome until the full blooming causes an increase of the crude fibre content and a deterioration of the quality of these plants.

The plants cultivated without irrigation contain greater percentages of dry matter than plants cultivated with irrigation.

Comparison of the chemical composition of plants grown in different parts of the country does not show any specific influence of the climate on the composition of the plants. The only exception seems to be the higher calcium content of lucerne grown in the Jordan Valley.

Table 1.
Average results of forage plant analyses (in the fresh matter)

Plant	Harvest- ing time (Month)	Growth period (in weeks)	Remarks	Percentage Chemical Composition							Feed unit in 100 kg		
				Water	Crude protein	Fat	Ash	Crude fibre	N- free extract	Calcium		Phos- phorus	Digest- ible crude protein
Trifo- lium Alexan- drinum Berseem	Nov.	6-7	First cut	89.1	2.4	0.3	2.1	2.5	3.6	0.26	0.04	1.9	8.7
	XIII	4-5	Sec. "	87.8	2.7	0.4	2.4	2.7	4.0	0.29	0.03	2.2	9.5
	I	5-6	Third "	90.9	2.0	0.4	1.6	1.9	3.2	0.21	0.03	1.6	7.2
	II	5	Fourth "	88.1	2.4	0.4	2.2	2.8	4.1	0.26	0.03	1.8	8.6
	III	4-5	Fifth "	86.4	2.8	0.4	2.2	3.6	4.6	0.27	0.04	2.1	9.5
	IV	4-5	Sixth "	83.2	3.5	0.5	2.0	4.6	6.2	0.39	0.05	2.9	12.6
	IV	2-3	" "	86.7	2.7	0.4	1.6	3.2	5.4	0.29	0.04	2.3	10.7
	V	5-6	" "	82.3	3.5	0.7	2.0	4.8	6.7	0.38	0.05	2.9	13.7
	III	8-9	First cut	86.1	2.8	0.3	2.1	4.2	4.5	0.26	0.03	2.1	9.7
	IV	6-7	Sec. "	80.8	3.4	0.7	2.1	5.5	7.5	0.40	0.05	2.9	14.0
Trif. Alex. Fahli	V-VI	7	Third "	76.7	4.1	0.6	2.3	7.5	8.8	0.43	0.05	3.1	15.1
	III	10-11	without irrig.	86.5	2.6	0.7	2.0	3.8	4.4	0.24	0.04	2.0	9.5
	IV-V	11-12	" "	82.0	3.4	0.9	2.3	5.2	6.2	0.41	0.04	2.8	13.8
	I	9	before bloom	89.5	2.0	0.3	1.6	3.2	3.4	0.19	0.04	1.6	8.2
	III	9-10	" "	87.4	2.6	0.4	1.7	3.2	4.7	0.20	0.04	2.0	9.7
Horse beans	III	12	begin. of bloom	85.0	2.5	0.4	1.8	4.9	5.4	0.22	0.04	2.0	11.4
	I-II	11-12	" "	86.8	2.3	0.4	1.7	4.4	4.4	0.19	0.04	1.8	9.9

Plant	Harvest- ing time (Month)	Growth period (in weeks)	Remarks	Percentage Chemical Composition							Feed unit in 100 kg		
				Water	Crude protein	Fat	Ash	Crude fibre	N- free extract	Calcium		Phos- phorus	Digest- ible crude protein
Field peas	I	9-10	before bloom	89.5	2.2	0.5	1.5	2.8	3.5	0.23	0.04	1.8	8.2
	III	9-10	" "	87.4	2.9	0.6	1.5	3.3	4.3	0.21	0.05	2.4	10.0
Cyprus vetch	I	11-12	begin. of bloom	87.1	2.9	0.5	1.6	3.6	4.3	0.21	0.04	2.4	10.0
	III	13	" "	85.0	2.9	0.6	1.4	4.2	5.9	0.23	0.05	2.4	12.1
Oats	I	4-5	before bloom	88.4	2.1	0.5	1.6	2.7	4.7	0.17	0.04	1.7	9.3
	III	6	" "	82.6	3.6	0.6	1.9	4.0	7.3	0.23	0.06	2.8	13.6
Lucerne	I	7	begin. of bloom	83.5	2.6	0.5	1.8	4.0	7.6	0.22	0.06	2.0	13.1
	III	8	" "	78.2	3.2	0.6	3.1	6.5	8.4	0.34	0.08	2.4	14.8
Oats	XII	6-5	before bloom	89.0	2.0	0.4	1.6	3.1	3.9	0.06	0.04	1.5	7.5
	III	10-11	" "	85.9	1.8	0.6	1.7	3.8	6.2	0.07	0.04	1.3	8.9
Lucerne	I-II	11-12	begin. of bloom	86.2	1.6	0.5	1.9	3.9	5.9	0.07	0.04	1.2	8.9
	III	15-16	" "	84.1	1.9	0.6	1.8	4.6	7.0	0.07	0.04	1.4	10.0
Lucerne	XI	2-2.5	before bloom	82.9	4.3	0.5	2.4	3.5	6.4	0.43	0.06	9.1	12.1
	II	3	" "	82.6	4.4	0.5	1.8	4.2	6.5	0.40	0.06	3.9	12.5
Lucerne	VI	2	" "	84.0	4.3	0.5	1.8	4.0	5.4	0.39	0.06	3.8	11.5
	VIII	2.5-3	" "	82.4	4.4	0.6	1.9	4.3	6.4	0.43	0.06	3.9	12.7

Plant	Harvest- ing time (Month)	Growth period (in weeks)	Remarks	Percentage Chemical Composition							Feed unit in 100 kg		
				Water	Crude protein	Fat	Ash	Crude fibre	N- free extract	Calcium		Phos- phorus	Digest- ible crude protein
Cow peas	XI-XII	4	begin. of bloom	77.8	4.9	0.8	2.6	5.8	8.1	0.47	0.07	3.9	14.5
	III	5	" "	76.8	5.4	0.9	2.7	5.6	8.6	0.47	0.07	4.3	15.2
	VI-VII	3-4	" "	77.6	5.2	0.8	2.5	6.1	7.8	0.46	0.07	4.1	14.7
	VIII	4-5	" "	77.0	5.2	0.8	2.5	6.1	8.4	0.52	0.07	4.1	15.2
	XII	6	in full bloom	70.6	5.3	1.0	3.0	8.9	11.1	0.48	0.06	3.7	14.5
	III	7-8	" "	71.5	5.3	0.9	3.1	8.1	11.0	0.44	0.07	3.7	13.9
	VII	6-7	" "	69.4	5.6	1.1	3.0	9.4	10.5	0.53	0.07	3.9	14.5
	VIII-IX	7	" "	71.7	5.6	1.0	3.0	8.3	10.4	0.58	0.09	3.9	13.7
	VII	7-8	begin. of bloom	87.1	2.4	0.5	1.8	3.5	4.7	0.24	0.05	1.7	9.0
	VIII	8-9	" "	86.6	2.3	0.4	1.7	3.6	5.4	0.25	0.05	1.7	9.5
Green maize	IX	8	" "	86.0	1.9	0.5	1.7	4.0	5.9	0.27	0.05	1.4	10.1
	VIII	11-12	bloom and	84.6	2.3	0.4	2.1	4.3	6.3	0.28	0.06	1.7	10.7
	VIII-IX	11	formation	84.8	2.3	0.5	2.1	4.3	6.0	0.32	0.06	1.7	10.7
	X	11	" "	84.7	2.0	0.4	1.8	4.4	6.7	0.33	0.06	1.4	10.8
	VI	6-7	for bloom	87.6	1.2	0.3	1.2	3.8	5.9	0.06	0.03	0.7	9.2
	VIII	6	" "	86.7	1.3	0.3	1.4	3.5	6.8	0.07	0.03	0.8	9.7
	X	7	" "	87.9	1.3	0.2	1.3	3.6	5.7	0.07	0.03	0.8	8.8
	VII	10	with- irrig.	81.8	1.6	0.4	2.0	5.8	8.4	0.10	0.04	0.9	12.0
	VIII	9-10	shocking	81.4	1.5	0.4	2.0	5.9	8.8	0.11	0.03	0.8	12.1
	IX	9	corn	81.9	1.8	0.4	1.8	5.2	8.9	0.10	0.04	1.0	12.0

Plant	Harvest- ing time (Month)	Growth period (in weeks)	Remarks	Percentage Chemical Composition							Feed unit in 100 kg		
				Water	Crude protein	Fat	Ash	Crude fibre	N- free extract	Calcium		Phos- phorus	Digest- ible crude protein
Green maize	VII	8-9	for bloom	84.1	1.4	0.3	1.7	5.1	7.4	0.09	0.03	0.8	11.3
	VIII	7	"	83.3	1.8	0.3	1.5	5.0	8.1	0.10	0.03	1.1	12.2
	XI	7	"	84.3	2.1	0.4	1.6	4.6	7.0	0.08	0.04	1.2	11.3
	VII	11	with- out	75.7	1.8	0.4	2.3	7.7	12.1	0.11	0.04	1.0	14.3
	VIII-IX	10-11	shocking irrig.	74.2	2.1	0.4	2.0	8.1	13.2	0.11	0.03	1.2	15.5
	XI	9	corn	78.1	2.2	0.3	1.9	6.9	10.6	0.10	0.04	1.2	13.0
Winter- some	VIII	10-11	for bloom	84.2	1.2	0.5	1.5	5.2	7.4	0.10	0.04	0.7	11.2
	IX	10-11	"	83.2	1.1	0.2	1.6	5.7	8.2	0.08	0.03	0.6	11.7
	IX	12-13	begin. of bloom	81.3	1.2	0.3	1.8	6.5	8.9	0.10	0.03	0.7	13.0
	X-XI	12-14	in full bloom	82.6	1.1	0.3	1.6	6.2	8.2	0.10	0.03	0.6	12.0
	VIII	14-15	in full bloom	75.2	1.2	0.4	1.7	9.2	12.3	0.13	0.04	0.7	14.3
	IX	15-16	"	75.4	1.0	0.4	1.9	9.1	12.2	0.14	0.04	0.6	14.0
Sun- flower	XI	14-15	"	76.5	1.2	0.3	2.0	9.7	10.3	0.14	0.04	0.7	13.2
	V	7-6	for bloom	90.2	1.4	0.2	1.6	2.2	5.4	0.18	0.04	1.0	7.5
	V	9-10	begin. of bloom	85.4	1.5	0.3	2.0	3.7	7.1	0.21	0.04	1.1	10.0
	V	8-9	for bloom	87.3	1.7	0.4	2.1	2.9	5.6	0.20	0.04	1.2	8.5
	V	11-12	begin. of bloom	84.5	2.0	0.4	2.4	4.1	6.6	0.23	0.05	1.4	10.4
	V	11-12	bloom	84.5	2.0	0.4	2.4	4.1	6.6	0.23	0.05	1.4	10.4

Plant	Harvest- ing time (Month)	Growth period (in weeks)	Remarks	Percentage Chemical Composition							Feed unit in 100 kg		
				Water	Crude protein	Fat	Ash	Crude fibre	N- free extract	Calcium		Phos- phorus	Digest- ible crude protein
Pas- palum	VII	2		77.5	2.8	0.5	2.2	8.8	8.2	0.12	0.05	2.2	15.0
	VIII	2		75.3	2.9	0.8	2.4	9.2	9.4	0.13	0.06	2.2	15.5
	VII	3		71.0	3.7	0.8	3.2	10.7	10.6	0.16	0.07	2.7	15.5
	IX	4		67.4	3.3	1.0	3.5	12.2	12.6	0.17	0.07	2.4	18.2
	XI	6		73.3	2.9	0.4	2.5	10.0	10.9	0.12	0.08	2.1	15.4
Rhodes grass	VII	2		76.8	2.7	0.9	2.3	8.1	9.2	0.13	0.07	2.1	15.8
	VIII	2		74.8	3.2	0.8	2.6	8.3	10.3	0.12	0.06	2.5	15.0
	VII	3		71.6	2.8	0.8	2.7	10.7	11.4	0.14	0.07	2.0	16.5
	IX	4		68.5	3.1	1.0	3.1	11.6	12.7	0.16	0.07	2.2	18.0
	XI	6		73.7	2.7	0.8	2.8	9.1	10.9	0.12	0.08	1.9	15.2
Man- gels			Species	Sugar									
	VI-VII	25-32	Eckendorf	2.7	91.0	0.9	0.1	1.1	6.0	0.05	0.03	0.8	8.3
	VI-VII	24-30	Mammut	6.1	89.2	1.2	0.0	1.2	7.5	0.05	0.02	1.1	10.3
			Golden										
	VI-VII	24-29	Tancred	4.5	88.0	1.0	0.0	1.3	8.7	0.06	0.03	0.9	11.5
	VI-VII	26-30	Sludstrup	3.7	89.1	0.9	0.0	1.2	7.7	0.04	0.02	0.8	10.3
Pump- kins													
	VII-VIII	18-26		92.4	1.1	0.2	0.6	1.0	4.7	0.03	0.02	1.0	7.7
Melon	VI-VIII	16-17		93.4	1.4	0.2	0.6	1.4	3.0	0.03	0.02	1.3	6.7

6.7

LIGHT DISTRIBUTION IN CITRUS TREES.^{(1)*}

BY

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Measurements of light distribution during different hours and seasons in individual citrus trees and in groves were made with a selenium barrier layer photocell (calibrated in lux units). Different varieties were also compared as to gradient of light penetration into the tops; interiors of Marsh Seedless grapefruit and Clementine mandarin proved much darker than those of Shamouti (0.6-0.9 vs. 2.0-4.0 of full sunlight, on the shady side). Thinning of very dense Shamouti groves improved both light conditions and crops of individual trees very considerably.

I. INTRODUCTION

The light factor is of paramount importance in determining the intensity of several processes of plant life, especially carbon dioxide assimilation and transpiration.

Several investigations have been published, on light conditions in natural habitats including "maquis" and woods^{2, 9, 16, 17}, but only little is known about the distribution of light in agricultural associations of plants and especially in fruit orchards^{4, 14, 17}.

On the distribution of light in the interior of the leafy tops of citrus trees as well as in the interior of citrus groves, considered as associations of trees, no research work has been published either in this country or elsewhere.

After a visit to Palestine many years ago Hodgson⁸ emphasized the importance of light for the production of heavy citrus crops and predicted that over-crowded groves would have to be thinned in the near future, to secure satisfactory yields. His prediction has proved true and a good deal of thinning work is now in progress to facilitate cheaper methods of soil cultivation and irrigation, as well as to provide a better supply of light to the remaining trees.

The present paper forms part of an investigation into the ecology of carbon dioxide assimilation by citrus trees and seedlings; further reports will be found elsewhere¹².

(1) This paper constitutes a chapter of the author's doctorate thesis, presented to the Senate of the Hebrew University in October 1949.

* Received June 1950.

II. METHODS

For the measurement of visible radiation, photochemical or photoelectrical devices may be used. The advantages and drawbacks of different instruments and methods have been discussed by several authors^{5, 11}.

Earlier authors, such as Wiesner¹⁹ and others, have used photometers provided with sheets of paper which are sensitive to restricted portions of the visible spectrum. Such devices yield only relative figures of light intensity. Selenium barrier-layer photocells have been used in the last fifteen years. They may be calibrated in absolute units, have an almost instantaneous reaction (10^{-8}sec)⁵ and are not seriously affected by changes of temperature¹¹. They are sensitive to about the same range of wavelengths as is the human eye.

We used a German selenium cell Lange of the type S 60, with a galvanometer calibrated in metre-candles or lux ($10\text{ lux}=0.93\text{ foot-candles}$), which, when compared in 1947 with a Weston illuminometer, yielded fairly concordant results.

The selenium cell was mounted on the tip of a stick one metre long, to allow the operator to keep it outside his shading or radiating influence. The galvanometer was mounted on a board which was kept in position by a tie slung over the operator's shoulder. By means of two light-filters and a switch on the galvanometer, light intensities between 1 and 190,000 lux could be measured.

Measurements in trees were taken both on horizontal surfaces and on planes parallel to leaf blades. Measurements outside the trees were in most cases made on a horizontal surface in the sun (full sunlight), but sometimes, instead, on a plane normal to the sun rays (direct radiation).

When investigating the illumination of even a very limited portion of a tree or a plant association one is struck by the extreme variability of data one obtains in spots situated at very short distances from each other. A statistical analysis of results is, therefore, impracticable in most cases, but whenever statistical methods could be applied in the present study, they have been used.

The results of light measurements were expressed in two ways:

- a) in absolute units [lux (L.) or kilo-lux (K.L.=1000 L.)],
- b) in percentages of full sunlight. The first way was chosen whenever possible; the second was preferred only when the use of absolute units had to be discarded for some reason.

It must be noted that relative units are sometimes useful, e. g., if one wishes to compare results with data of earlier workers who were obliged to indicate their results in relative units, being unable, as a consequence of primitive methods, to arrive at absolute figures.

Some students² have calculated percentages of daylight instead of percentages of full sunlight. This may be useful in dull cloudy climates where full sunlight could not

possibly be measured as a rule. But since on bright days, which are the rule in this country, plenty of sun-flecks are found in shaded places, we prefer percentages of full sunlight.

According to Ashbel¹ cloudiness is very low in the main citrus belt of Israel. At Ramle (some 6 kms NE of Rehovot, where most of our light measurements were taken), the annual minimum of actual sunny hours (occurring in January) is 60% of the possible monthly total (193 hours). From May to October we find more than 80% of the possible monthly total, the maximum being 91% in July.

In the present study the illumination at a certain spot was often expressed by means of a frequency histogram. In order to facilitate presentation, and for physiological considerations (Lundegardh¹⁰), classes of light intensity were not made equal as is customary, but grow progressively larger with growing intensities, according to a geometrical progression of ratio 2 or 4. Such a logarithmic arrangement of illumination is also suggested by the lower degree of sensitivity of the measuring instrument at high intensities.

III. MEASUREMENTS IN THE OPEN

Measurements of full sunlight (on a horizontal plane) and occasionally of direct radiation (on a plane perpendicular to the sun rays) were taken on different days during the period of the present investigations (1945-1947). As no data on illumination in the open, measured by a selenium cell, have so far been published in this country, and as the foreign literature is also very scanty, it has been deemed desirable to give a brief account of our results in this paper.

On bright days, about the beginning of each astronomical season, several measurements of full sunlight were taken, concomitantly with ecological measurements which will be dealt with later on. They are presented in Table I.

It is easily understood that the graphical presentation of the data does not result in smooth daily curves of illumination, although bright days were chosen. Nevertheless Table I allows some insight into the daily course of illumination on a horizontal plane in the open, as influenced mainly by the altitude of the sun in the different hours of the day and the various seasons of the year. When clouds are involved, much greater fluctuations of light intensity take place. Measurements taken on November 27, 1946, a cloudy winter day, showed us that figures obtained were too variable to permit the calculation of representative averages. In the period between 09.50 and 09.52 on that day, the intensity of light dropped from 46 to 8 K.L. and was 25, 46, 53 and 62 K.L. at 10.03, .04, .06 and 10.14 respectively! Such major fluctuations were recorded several times during the day, while smaller ones of 5-10 K.L. were the rule.

In certain cases simultaneous measurements of full sunlight and direct radiation

were carried out. On November 6, 1947, a bright day, full sunlight was about 50% of direct radiation at 08.50 while it rose to 70% at 12.15 E.E.T.

TABLE I.

Full sunlight measurements on different bright days, at Rehovot ($31^{\circ} 54'N$). (Kilo-lux)

Hour of day (E.E.T.)	Sept. 17, 1946	Dec. 17, 1946	Dec. 18, 1946	Mar. 20, 1947	June 26, 1947	June 27, 1947
07.30	27	—	5.6	29	—	51
07.40	37	—	8	34	—	51
07.50	42	—	8.5	36	—	51
08.00	44	—	12	47	—	54
08.10	46	—	15	45	—	58
08.20	54	—	20	45	—	58
08.30	54	—	21	50	—	60
09.30	70	—	—	50	79	—
09.40	75	52	—	66	89	—
09.50	76	52	—	68	89	—
10.00	74	52	—	86	93	—
10.10	76	52	—	82	96	—
10.20	78	52	—	83	102.5	—
10.30	78	52	—	85	99	—
12.10	85	58	—	95	105	—
12.20	92	58	—	95	104	—
12.30	102	56	—	97	101	—
12.40	99	56	—	95	95	—
12.50	89	56	—	93	98	—
13.00	88.5	56	—	95	101	—
13.10	78	—	—	93	99	—
13.20	—	—	—	93	99	—
14.20	57	39	—	59	79	—
14.30	65	39	—	59	76	—
14.40	63	25	—	59	76	—
14.50	64	26	—	58.5	78	—
15.00	45	26	—	42	70	—
15.10	43	26	—	47	70	—
15.20	41	—	—	50	—	—

IV. ILLUMINATION OF INDIVIDUAL LEAVES

It seemed desirable to investigate the illumination on different hours and days of the assimilating units of the tree — the single leaves — according to their position in the leafy top. In light measurements only the ventral (upper) side of the leaves was considered; this is justified by leaf structure and orientation.

One series of measurements was performed on May 21, 1946, at Rehovot. Its arrangement was somewhat similar to that used by Christopher⁴ in his work on apple trees. Five leaves of different inclination were selected at about 1.50 m. from the soil on all four sides of a Marsh Seedless grapefruit tree, in an orchard in which trees were planted in equilateral triangles 5 metres apart. Illumination was measured every 15 minutes for 9 hours. The most interesting results were found with respect to vertical and horizontal leaves exposed to the four cardinal directions. The curves of illumination for each leaf, plotted against time, were drawn and planimeted. Vertical leaves were found to be struck by radiation in a way similar to that reported by Ashbel¹ for stone walls of the same exposure. The comparison of horizontal leaves with a horizontal plane in the open, however, is not fully justified, as they were not struck by uniform illumination. Generally speaking, horizontal leaves received more light than vertical ones (339.6 K.L. hours on the average as against a maximum of 307 for vertical leaves) but much less than a horizontal plane in the open (612.5 K.L. hours).

TABLE II.

Daily illumination of vertical and horizontal leaves at various exposures, on May 21, 1946, as compared with radiation falling on vertical walls.
(Maximal sun altitude, at noon: 78°)

Exposure	Vertical leaves	Vertical leaves	Walls	Horizontal leaves	Horizontal leaves
	(K. L. hours)	Daily illumination (% of East)	Daily radiation (% of East)	(K. L. hours)	Daily illumination (% of East)
East	307	100	100	371	100
West	270	88	100	300	81
South	70	22.8	29.8	295	79
North	60	19.6	19.8	392.5	106

The above measurements indicate the importance both of the degree of inclination of the leaves and of their exposure, with respect to the intensity of the light which falls on them during the day.

After these preliminary measurements we decided to carry out further experiments

in a different manner. A great number of leaves were selected at random from various small portions of the leafy top, which were considered as representative for the different exposures. For these extensive investigations one Shamouti orange tree, budded on sweet lime stock, was selected in a grove of the Agricultural Research Station at Rehovot. In this grove the trees are planted in squares at 4 metres distance, the direction of rows being NNW to SSE. Four times two series of 200 light measurements were carried out on every day of measurement. In each of the four cardinal directions the intensity of the light falling on 50 random leaves at the periphery, and on 50 random leaves in the interior of the top was measured. In order to select leaves from about the same portions of the top, on different occasions, four rings of iron wire, one metre in diameter, were laid down on branches in a position tangential to the periphery of the top: their centres were about 1.30 m. above the soil. Leaves were always selected in the portions of the top circumscribed by rings. The measurements (8,000 *in toto*) were carried out on the days detailed in Table I (bright days) and on one cloudy winter day, November 27, 1946. The results have been plotted in frequency histograms (Figs. 1 and 2 as described above. Sums of 50 measurements taken on each "occasion" are recorded in Table III. Every set of 50 measurements took about 5 to 10 minutes, so that two complete tours of the tree, the first for the measurements at the periphery, and the second for the measurements in the interior, were accomplished in about one hour.

The great differences between the light-climate of the periphery and that of the interior of the top are evident from both Table III and histograms. In the interior of the top most values are well under 3 K.L. and figures of only a few hundred lux are often found. At the periphery most shade values are between 3 and 6 K.L.; in sun-flecks and full sun figures between 15 and 75 K.L. are found as a rule, while extremes above 100 K.L. may be found, especially in March. According to Ashbel⁷, radiation on a plane normal to sun-rays is at its maximum in March. A much greater uniformity was found among leaves in the interior of the top than among those at the periphery. Some of the major differences in the interior of the top could be traced to a different number or area of sun-flecks, or to differences in the pattern of the tree in its various parts. The average illumination of leaves followed the daily course of solar radiation more strictly at the periphery than in the interior of the top. Maximum illumination was, therefore, found on eastern leaves in the early morning; on southern, in the middle of the day; and on western, in the late afternoon.

Two interesting features were noted in the December measurements. During the first daily set of measurements before 08.00, only diffuse light was measured, since sun rays were intercepted by wind breaks. In all exposures, recorded light values were relatively uniform and low. Only on the southern flank of the tree, where measurements were taken when the direct rays of the sun began to strike it from above the wind breaks,

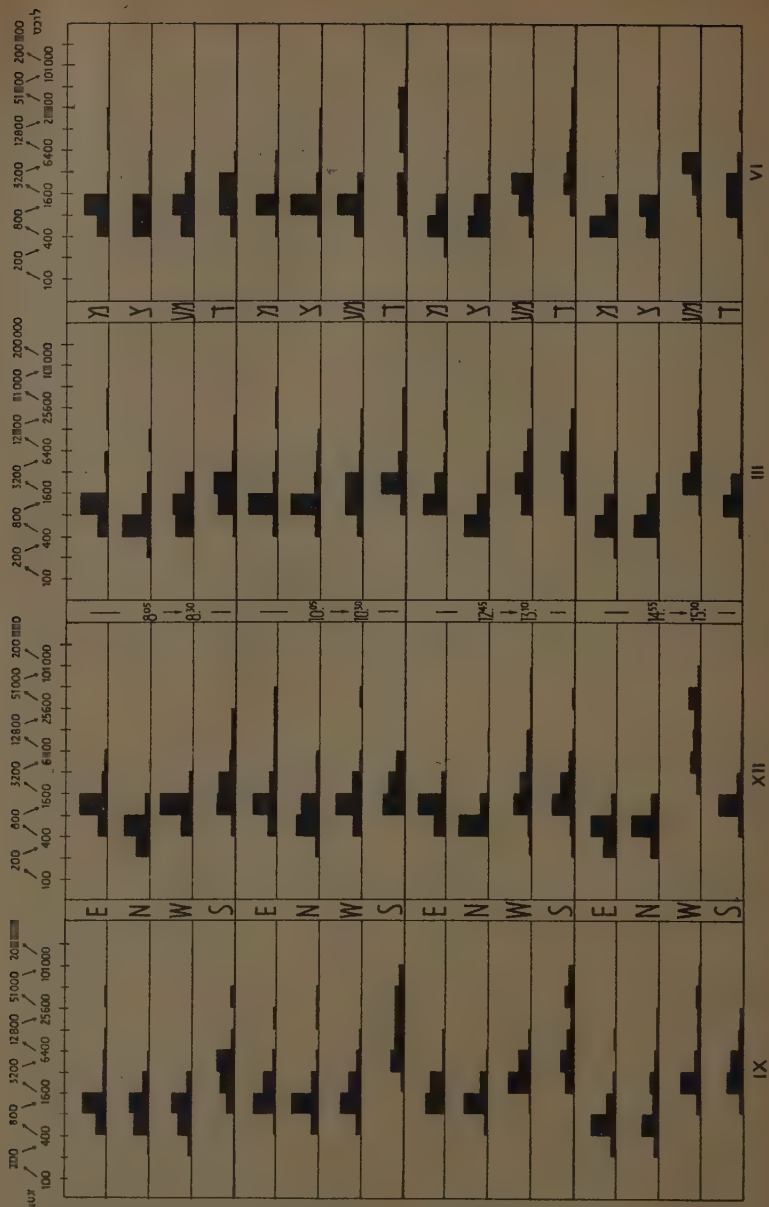


Fig. 1. — Histograms of measurements taken on leaves situated in the interior of the top. Measurements were taken on different flanks of the tree, at various hours and days.
Total measurements $(50 \times 4^3) = 3200$.

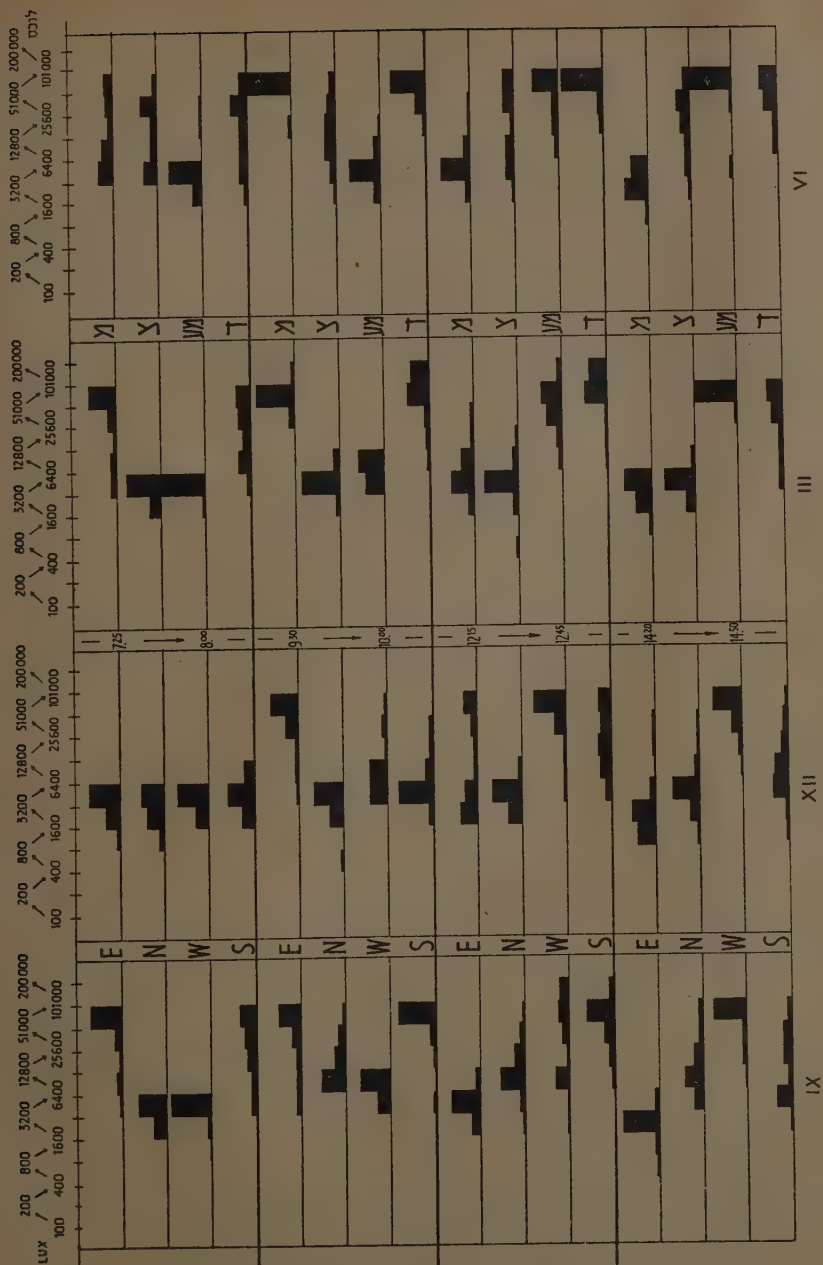


Fig. 2. — Histograms of measurements taken on leaves situated at the periphery of the top. Measurements were taken on different flanks of the tree, at various hours and days. Total measurements (50×4^2) = 3200.

were higher values found. During the whole day, however, lower values were recorded on the southern flank than would be expected. This can be explained by the low altitude of the sun on winter days (max. 35° at noon on the winter solstice): the southern flank of the tree was thus shaded by the adjoining tree on the south.

On the other hand, in June, values on the northern flank were sometimes higher than expected. This may be ascribed to the higher altitude of the sun (max. 81° at noon on the summer solstice) and to its northern declination, in both morning and afternoon.

In Table III, mean values of measurements taken in the interior of the top have been calculated as percentages of measurements taken at the periphery. When external

TABLE III

Comparison between totals of 50 measurements of illumination of the interior and periphery made at varying tree quadrants, days and hours [expressed in M.L. (Megalex=1000 K.L.) and %, where periphery totals=100].

Direction	Time of the day (E.E.T.)							
	07.35—08.30		09.30—10.30		12.15—13.10		14.20—15.10	
	%	M.L.	%	M.L.	%	M.L.	%	M.L.
September 19, 1946								
EAST periphery		2.742		2.481		.231		.125
interior	3.4	.094	5.1	.127	53.2	.123	38.4	.048
NORTH periphery		.214		.975		.721		.916
interior	28.5	.061	16.4	.158	12.4	.089	9.6	.095
WEST periphery		.228		.364		2.374		3.343
interior	21.5	.049	27.2	.099	7.2	.171	13.5	.453
SOUTH periphery		1.967		3.473		3.431		1.064
interior	14.7	.288	27.6	.959	29.9	1.028	21.8	.232
December 17/18, 1946								
EAST periphery		.181		2.824		1.191		.143
interior	32.0	.058	5.8	.164	4.6	.055	25.9	.037
NORTH periphery		.171		.191		.193		.275
interior	16.9	.029	22.5	.043	28.0	.054	12.0	.033
WEST periphery		.202		.762		3.300		2.965
interior	26.2	.053	13.1	.100	7.6	.253	33.7	.906
SOUTH periphery		.227		.327		1.602		.620
interior	67.8	.154	30.0	.098	7.3	.117	25.5	.158

Direction	Time of the day (E.E.T.)							
	07.35—08.30		09.30—10.30		12.15—13.10		14.20—15.10	
	%	M.L.	%	M.L.	%	M.L.	%	M.L.
March 20, 1947								
EAST periphery		2.560		3.764		.493		.162
interior	4.1	.104	3.2	.121	34.3	.169	30.8	.050
NORTH periphery		.192		.303		.299		.227
interior	24.5	.047	25.7	.078	16.4	.049	19.8	.045
WEST periphery		.227		.347		.3123		4.124
interior	24.2	.055	30.0	.104	10.0	.310	9.4	.437
SOUTH periphery		1.783		4.007		4.276		1.984
interior	6.9	.124	10.4	.418	10.2	.434	7.0	.139
June 26/27, 1947								
EAST periphery		1.212		3.944		.394		.153
interior	6.9	.083	1.8	.072	11.9	.047	26.8	.041
NORTH periphery		1.103		1.172		1.511		1.650
interior	5.7	.063	6.0	.071	3.2	.048	8.2	.136
WEST periphery		.269		.265		2.989		4.063
interior	21.6	.058	23.4	.062	2.7	.082	5.9	.240
SOUTH periphery		1.347		3.092		4.052		2.405
interior	5.9	.080	20.0	.619	12.8	.520	4.3	.103
November 27, 1946 <i>Cloudy day</i>								
EAST periphery		.056		.728		.703		.172
interior	62.5	.035	51.5	.372	10.5	.074	19.8	.034
NORTH periphery		.130		.282		.576		.278
interior	39.9	.046	35.1	.099	15.1	.087	22.6	.063
WEST periphery		.189		.275		2.392		.441
interior	24.4	.046	32.4	.089	24.1	.577	15.1	.069
SOUTH periphery		.290		.393		2.059		.267
interior	86.9	.252	104.	.407	45.7	.942	43.8	.117

leaves were struck by direct sun-rays, internal values represented only a small fraction of external values. But when light at the periphery was of a diffuse nature, internal values were proportionally much higher (see, *e.g.*, those sides of the tree which are shaded; or measurements taken on a cloudy day).

V. ILLUMINATION OF DIFFERENT LOCATIONS IN TREE TOPS

Illumination in different locations in the tops of trees was measured with the light-sensitive surface of the selenium cell held horizontally and upwards. To obtain comparable sets of measurements it was necessary to mark exactly the different spots where illumination was to be measured. At a first attempt, the selected locations in the tops of one Shamouti orange and one Marsh Seedless grapefruit tree — both used in experiments previously described in detail—were marked with wooden labels. This however, proved impractical, as the labels could not be fastened in exactly the desired place in every case. Measurements according to this method were carried out in the two trees during one bright winter day (January 17, 1946). As only 36 places were marked in each tree, we were unable to establish the clear-cut gradient of light intensity which is to be expected if light measurements are taken in a centripetal direction beginning with the periphery of the top. The main difficulty was again due to the considerable variability of values produced by irregular interactions of leaves, branches and sun-rays.

It was established that a greater amount of light penetrates the more open top of the Shamouti tree than the denser top of the grapefruit. The system of planting and the distances between the trees proved important, owing to the low altitude of the sun throughout the day.

On this day many measurements of "albedo" (i.e., reflected radiation) were taken, with the sensitive surface of the instrument turned towards the soil and kept parallel to it.

The ratio of albedo to illumination falling in from above was low when measurements were taken in the sun ($1/10$ — $1/50$), but much higher when they were taken in diffuse light ($1/2$ — $1/5$). When they were taken in the densest parts of the tops, rates in the neighbourhood of 1 and even more were found.

Fixed nets of wires kept under tension proved unsuitable as a device for marking a greater number of loci, symmetrically distributed in the top of a tree, since too many were necessary to study different trees. A simple, transportable frame was eventually devised. It consists of two sticks about 2.50 m. long, connected every 25 cm. by strings which are marked at intervals of 20 cms. One of the sticks was fastened to the trunk of the tree to be investigated, while the other was stuck into the soil at its periphery. Eight such radially arranged frames can be set up for each investigation and light measurements taken at the marked spots. This allows us the subsequent mapping of the shape of the top either as profile or as projection, and the registering of light intensities on the charts by means of symbols and figures, as shown in Fig. 3. The results are better expressed as percentages of full sunlight than in lux units unless a prolonged study of the illumination of only one tree is planned.

It was found from several series of measurements that a clear-cut gradient of illu-

PERCENTAGES OF FULL SUNLIGHT

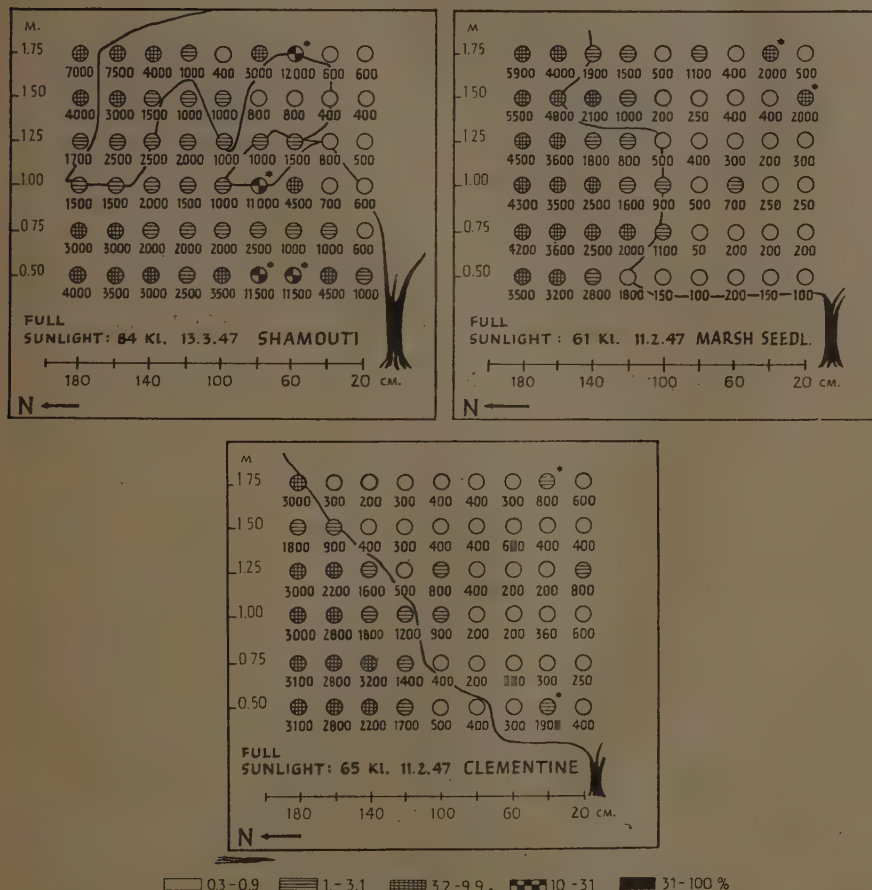


Fig. 3. — Illumination on the northern flank of different citrus trees. Percentages of full sunlight registered in small circles; beneath them, corresponding figures in lux units. Sun-flecks are indicated by asterisks.

mination towards the interior of the top is by no means the rule. This is especially true for that side which is exposed to the sun, where more or less frequent sun-flecks are found in the interior of the top and the resulting picture is rather confused. It is nevertheless obvious that a lower average light intensity will be found in the interior than at the periphery. It was therefore decided to measure the interior illumination of different varieties on the northern side only.

(1) *Penetration of light into the tops of several citrus varieties*

Figure 3 shows the interior light intensities and the profile of the northern flanks of one Shamouti orange, one Marsh Seedless grapefruit and one Clementine mandarin tree. Percentages of full sunlight are registered in small circles which indicate the points where measurements were taken, while figures represent actual illumination in lux units. Table IV sums up the results.

TABLE IV
Illumination on the northern side of citrus trees. (See Fig. 3)

Percentages of full sunlight	Frequency of intensities of illumination in the interior of tops of three citrus varieties (% of n, the total number of measurements)		
	Shamouti orange	Marsh grapefruit	Clementine mandarin
	n=25	n=35	n=34
less than 1%	32%	69%	85%
1%—2%	36	14	12
2%—3%	8	6	3
3%—4%	16	11	0
4%—9%	8	0	0
more than 9%	0	0	0
	100	100	100
Percentages of full sunlight			
Average illumination except at spots with sun-flecks	2.06±0.37	0.94±0.16	0.62±0.05

On a khamseen day (sirocco), when diffuse light was stronger (February 14, 1947), even higher illumination was found in the interior of the same Shamouti orange tree (4.24 ± 0.66). Although the value of a test of significance may be questioned in such cases, it should be stated that the difference between mean illumination in Shamouti (see Table IV) and both other varieties was found highly significant, while that between grapefruit and Clementine is just below the threshold of accepted significance ($p=0.05$).

(2) *Illumination in citrus groves, between the trees*

On several occasions light intensity was measured in citrus groves without the help of any frame or device, by placing the illuminometer in different locations and recording the distances from trees, soil and open places.

On May 26, 1946, a fairly bright day, measurements were taken during the morning hours in a very dense grapefruit grove at Rehovot. The trees, planted according to the rectangular system (4 x 4.50 m.), were very well developed, the lower branches having been pruned. Almost all fruit was borne on the upper branches, forming a closed canopy. (Such plantations are sometimes called "silk hat groves" by American horticulturists.) No more than 5% to 10% of the soil was spotted with sun-flecks at the time of our measurements. Measurements on a horizontal plane showed a statistically significant gradient of illumination from the soil upwards and from the trunk outwards. An average of 0.66% of full sunlight was found at a horizontal distance of 50 cm. from the trunk and at the same distance above soil level; while 0.97% and 1.22% were averaged at 1.50 m. from the trunk and at 50 cm. and 1.50 m. respectively, above the soil. Notwithstanding such differences, all these values are very low. Leaves are shed as a consequence and only a few large and dark-green leaves can be found in such deep shade.

Near the trunk of one tree bordering upon an open, illuminated space, 7.6% of full sunlight was recorded in the shade, while midway between this tree and the next one in the row only 0.98% was found. Near the trunk of the second tree illumination was 0.68%. Measurements on individual leaves gave similar results.

On November 6, 1947, again in the morning hours, measurements were taken in the unthinned portion of a grove at Raanana. The trees are Shamoutis on sweet lime stock, planted 4 metres apart, according to the square system. As the trees were very crowded, the average relative illumination found in 200 measurements which were taken on leaves at four different positions was as low as 0.725% $\pm$ 0.077.

In the interior of the top of citrus trees some leaves are often found hanging in a vertical position. In all cases, it was observed that the leaves are orientated in such a way as to receive the highest illumination possible in such dark places. Wiesner's law¹⁹ of the "fixe Lichtlage" was therefore confirmed in the case of citrus trees.

VI. IMPROVEMENT OF LIGHT CONDITIONS AS A CONSEQUENCE OF THINNING

Light measurements were carried out in thinned and unthinned portions of groves where experimental work on thinning (by the Division of Citriculture of the Agricultural Research Station, Rehovot) was in progress.

Of high interest are the results obtained in the extremely dense grove at Raanana mentioned above. Here, thinning was done by uprooting diagonal rows of trees planted in squares. 50% thinning was obtained by uprooting every second row, and 33% by uprooting every third row. The distances thus produced in plots thinned at different degrees can be seen from Fig. 4. While in unthinned plots, as well as in those

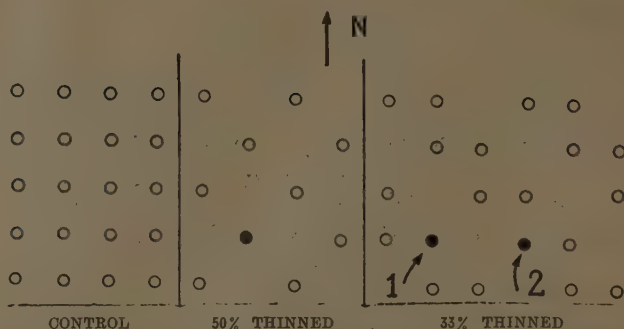


Fig. 4.—Schematic map of controls and thinned plots in the grove, at Raanana.

thinned by 50%, all trees enjoy uniform illumination, two different types of illumination are found in plots where only 33% of the trees were removed. There are trees having an open space on their northern and eastern flanks (as tree No. 1) and others enjoying good conditions of illumination on their southern and western flanks (as tree No. 2). The diurnal sum of radiation received by the former must necessarily be lower than that received by the latter.

Fig. 5 shows the results of measurements taken on leaves in the plots and at the exposures indicated. These were taken on November 6, 1947, a bright day, between 08.30 and 11.20 E.E.T.; the results are expressed in percentages of full sunlight. Each column represents the sum of 50 measurements. The ordinate is logarithmically graduated.

The enormous difference in total illumination between control plots and plots thinned by 50% is striking (0.72% as against 51.2% of full sunlight, measured on leaves at the periphery of the top). The plots thinned by 33% receive illumination intermediate between controls and heavily thinned plots (tree No. 1, 16.8% and tree No. 2, 25.3%). The difference between tree No. 1 and 2 would have been even greater if the measurements had been taken in the middle of the day instead of in the morning.

These and further measurements showed that trees of the "33%-plots" enjoyed better illumination on the "crowded" side than trees of the control plots, while their gradient of illumination towards the trunk on sides opened by thinning was similar to that of trees in the "50%-plots".

The results of our illumination measurements show a positive correlation with yield per tree. As we were informed by Mr. Y. Patt, (formerly of the Division of Citriculture at the Agricultural Research Station, Rehovot), trees from the "50%-plots" bore about double the yields of unthinned controls, two years after thinning (i.e., at about the time when our measurements were carried out), while trees from the "33%-plots" yielded crops intermediate between "50%-plots" and unthinned controls.

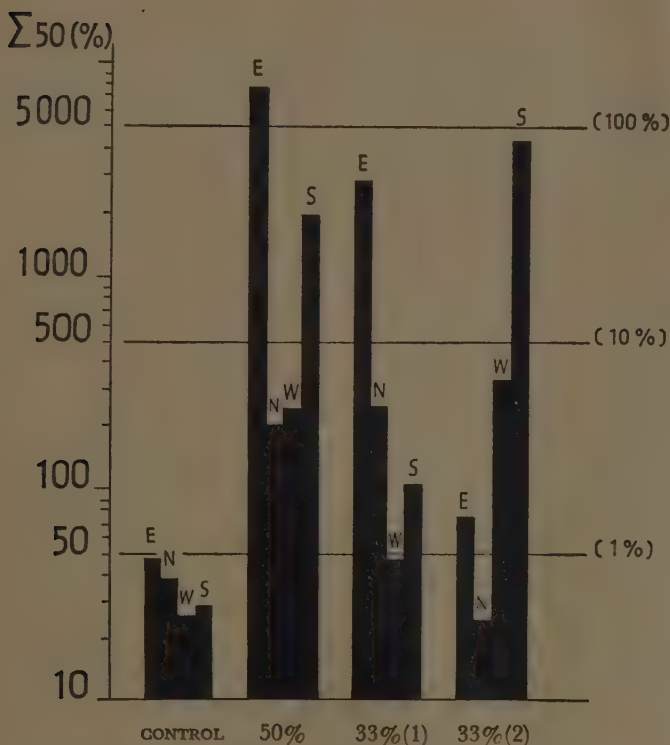


Fig. 5. — Sums of measurements taken on fifty leaves at the periphery of the tops, at the exposures and in the plots indicated. (In parentheses, mean percentages of sunlight).

VII. DISCUSSION

Citrus trees may be termed relatively shade-loving or sciophilous, at least in regard to their early vegetative stage of growth. Such a view, which had already been held by previous workers⁶, was borne out by a study of comparative growth of sweet lime seedlings in the shade and in the full sun, published elsewhere¹². It is also confirmed by the fact that their shade-leaves can survive at light intensities of much less than 1% of full sunlight. Burkholder³ calls *Aspidistra elatior* "an extreme shade plant" as it can thrive at 0.5% of full sunlight, while Loomis⁷ states that few flowering plants can survive on a forest floor, where the light intensity is less than 2%.

Values ranging between 0.5% and 2% of full sunlight have been found as a rule in the interior of the tops of citrus trees, especially in the varieties having a dense top, such as the Clementine mandarin or the Marsh Seedless grapefruit. It should, be

noted, however, that only some of the leaves are found growing in such extreme shade; other leaves, enjoying better illumination, may contribute to their survival.

Citrus seedlings may be grown with some success under partial shade¹⁸, and sometimes even mature orchards are interplanted with tall avocados or palms which throw their shade on the neighbouring citrus trees. Such a practice may be justified in hot, bright climates by the fear that intense radiation may have deleterious effects on leaves and delay photosynthesis, as has been shown by Nutman¹⁸ for coffee leaves, and by other authors for other plants (Stalfelt¹⁶).

It should, nevertheless, be pointed out that full sunlight is necessary for obtaining the maximum yield in citrus trees. This is the opinion of both laymen and experts (see Hodgson⁸) and is amply corroborated by the study of the increment in yields of thinned orchards, correlated with improvement of light conditions.

It might seem contradictory that, while photosynthesis may efficiently proceed in half-shade, perhaps even better than in full sunlight¹², maximum yields are obtained only on those portions of the top which are fully exposed to the direct rays of the sun. Sun rays may have favourable effects on blossoming and fruit set, besides providing the energy necessary for the production of photosynthates. But it must be noted that high illumination values are found only on the outermost external leaves. Some inches inside the top, illumination already drops to lower values, even on the sunny flank of the tree; and even if sun flecks are found, they do not remain for more than a few minutes in the same place. It should be added that, according to various authors, intermittent illumination is conducive to high photosynthetic activity, (see, Thomas and Hill⁷).

SUMMARY

The distribution of light in the leafy top of citrus trees was investigated by means of a Selenium barrier-layer photocell.

Measurements taken with the cell held parallel to leaf blades enabled us to draw extensive frequency histograms of leaf illumination on different days, and at different hours and exposures.

Measurements taken with the cell held horizontally and upwards proved useful in the investigation of the illumination of different locations in the interior of tops of citrus trees. Clementine mandarin and Marsh Seedless grapefruit trees were found to have a significantly denser leafy top than Shamouti orange trees.

As a consequence of thinning of over-crowded groves, light conditions were found to be highly improved, and yield per tree was greatly enhanced.

Owing to the high shade-tolerance of their shade-leaves, citrus trees may be termed "sciophilous trees" at least in regard to their vegetative stage of growth. Full sunlight is nevertheless required for obtaining the maximum yields.

The author is very much indebted to Prof. H. R. Oppenheimer, who suggested the subject of this study and gave invaluable help during both the experiments and the final preparation of the manuscript.

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ESTIMATION OF THE INCIDENCE AND DESTRUCTIVENESS OF PLANT DISEASES

II. EVALUATION OF ESTIMATES AND USES OF ESTIMATIONS^{(1)*}

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In the estimation of plant diseases the data collected by visual appraisal may be coordinated to arrive at a single expression defining the incidence of disease, which is termed the "disease rating". In some cases of defoliating diseases the incidence of disease on leaves that have been shed may be taken into account.

The destructiveness of disease consists in its effect on the size and quality of the yield. The effect of disease on the size of yield depends, in addition to the incidence of disease, on the stage of host growth at which the disease appears, the vigour of the host plant, the rate of disease development, and its intensity (or inherent destructive energy).

In view of the fact that none of these factors is capable of accurate quantitative expression, it is concluded that the incidence of disease cannot readily be interpreted to indicate the destructive effect of disease on the size of yield. The limitations of some of the methods proposed for such interpretation are pointed out.

The estimated incidence of disease directly affecting the quality of agricultural produce is a fair indication of the destructiveness of such diseases.

EVALUATION OF ESTIMATES

The estimation of incidence of disease by means of one or an other of the systems of categories outlined in part I of this paper makes it possible to define the extent of disease development with some accuracy, but does not enable us to express the amount of disease on one in relation to that on other plants, or parts of plants, and to compare the incidence of disease during successive seasons. As this is necessary in the majority

⁽¹⁾ Part I of this paper, dealing with terminology and the technique of visual appraisal, has appeared in Vol. I, nos. 1-2, of this Bulletin on pp. 76-97 (1951).

* Received May 1951.

of cases, numerical values have to be attributed to each one of the categories of appraisal. Such numerical values of necessity introduce a certain arbitrariness into the evaluation of estimates, as the exact values to be chosen for each category are always a matter of some doubt, but there appears to be no other way of reducing an estimate, or group of estimates, to a single expression comparable with other estimates.

Numerical evaluation is usually applied to estimates of the prevalence of disease and the frequency of occurrence of the various degrees of infection. Estimates of the type of infection are less frequently evaluated in this way. But Levine, Stakman & Stanton⁴⁰ assign numerical values to the different types of infection of *Puccinia graminis* on various oat varieties and arrive at a figure expressing the general resistance or susceptibility of a variety to stem rust by multiplying this value with the numerical value attached to the degree of infection exhibited by the variety. Murphy *et al.*⁵² have used the same procedure in their work with crown-rust of oats. Rashevskaja & Yatsinin⁵⁸ have likewise attached a definite numerical value to each of the types of infection caused by *Bacterium malvacearum* on cotton. In the following, we shall consider only the evaluation of estimates of the prevalence and of the degrees of infection.

The unit of evaluation may or may not coincide with the unit of visual appraisal. Thus in the case of the cucumber mildews cited in part I, (p. 89), where each leaf was appraised separately, evaluation of the estimated incidence of disease per plot may take the form of simply averaging the numerical values attached to the estimates of each leaf; in that case the unit of evaluation coincides with the unit of estimation. Alternatively, however, an average of the numerical value of the estimates applied to all the leaves of a given cucumber vine may be calculated and the figures thus obtained for each vine may be averaged to indicate the incidence of disease on the plot; in this case the unit of estimation is still the leaf, but the unit of evaluation of disease incidence on the plot is the vine. Similarly, in the methods of assessing the incidence of cereal rusts proposed by Ducomet & Foex¹⁵, single organs of the plant (stems, leaves, leaf sheaths, ear) or parts of such organs are used as units of appraisal but the plant as a whole is considered the unit of evaluation.

As pointed out in the introductory chapter of this paper, the evaluation of data collected by visual appraisal may be limited to the mere computation of the general incidence of disease from the mass of individual records of the prevalence and frequency of occurrence of each degree of infection of disease or may aim at assessing the destructiveness of the disease, i.e., the economic loss caused by it.

A. COMPUTATION OF THE INCIDENCE OF DISEASE

The incidence of disease is computed by attributing to each category of appraisal a numerical value or mark, on the basis of the area of tissue affected. Any convenient unit of area, e.g. one tenth or one third of a leaf, may be adopted for this purpose as

representing one mark. If the unit of evaluation is identical with the unit of appraisal, the total of marks for all units appraised on a given plot is divided by the number of those units. The resulting figure may be regarded as an expression of the state of infection of the plot^{60, 69} and may be termed the "disease rating"²⁸ or "infection rating"⁴⁷ or the "coefficient of infection". Alternatively, this figure may further be divided by the numerical value attached to the highest category of infection and then multiplied by 100, and the result expresses the state of infection of the plot as percentage of the highest possible degree of infection^{34, 47, 58, 68, 68, 74}.

Example: If 20 plants in a plot are estimated on a scale ranging from 1 to 8 marks, and the aggregate marks amount to 80, the disease rating may be stated to be $80 \div 20 = 4$; or the aggregate may be divided by the highest possible total of marks, $(8 \times 20) = 160$, and multiplied by 100, i.e. $(80 \div 160) \times 100 = 50$, so that the incidence of disease may be stated to have reached 50% of the highest possible incidence.

If the unit of evaluation is composed of two or more units of appraisal (e.g., if leaves have been appraised separately but evaluation is to be based on the degree of infection of each branch or plant), the marks attributed to each component part must first be totalled (or averaged); the resulting figure indicates the degree of infection of the branch. The further computation of the incidence of disease on the whole plot then follows the lines stated above.

It must be clearly understood that the incidence of disease, computed in this way, takes into account only the relative area of diseased tissue but not the fact that equal areas of such tissue may differ greatly in their effect on the plant according to whether young or old parts have been attacked.

The evaluation of data concerning the shedding of leaves presents many problems. In the case of olive leaf spot (*Cycloconium oleaginum*) we have found it convenient — as described elsewhere at length⁵⁷ — to compute the incidence of disease on shed leaves in the same way as that of leaves persisting on the tree. In this way we obtained an average disease rating for shed leaves, and this rating could be applied to each of the leaves found to have been shed from the twig examined. Thus the disease rating for persisting leaves plus the average rating for shed leaves multiplied by the number of leaves shed will yield the grand total of marks applicable to the twig. If this grand total is divided by the total number of leaves on the twig, we obtain an overall disease rating for the twig.

Example: If the twig originally had 25 leaves, of which 18 persisted and were assigned a total of 41 marks, and if the average rating for shed leaves was 2.5, then the marks for 7 shed leaves (17.5), added to those for persisting leaves (41), give total marks of 58.5. Dividing this total by 25 we obtain 2.34 marks as overall disease rating for the twig.

B. ASSESSING THE DESTRUCTIVENESS OF DISEASE

1. *Effect on the size of yield*

The problem of translating the computed incidence of disease into figures reflecting its effect on the size of yield is extremely complex. The final incidence of disease represents only one of a number of factors conditioning this effect, the remaining factors being

- i. the stage of host growth at which the disease appears;
- ii. the rate of disease development;
- iii. the vigour of the host plant;
- iv. the intensity of the disease.

Adequate quantitative expressions have to be found for each of these factors in order to enable us to assess the destructiveness of disease on the basis of the estimated incidence. Examining them in turn, we shall now proceed to discuss the extent to which each of these factors is capable of such quantitative expression.

(a) *Stage of appearance and rate of development.*

The stage of growth reached by the host before it is attacked by disease and the subsequent rate of disease development are of evident importance for the extent of the damage caused. The scale devised in the United States⁴⁸ for assessing the effect on the yield of various incidences of rust at various stages of cereal growth is based on the assumption that the rate of disease development in different years is more or less uniform. Roussakoff & Patchenko⁶⁵ and other writers^{15, 30} have pointed out that in some cases the yield may suffer but little where disease develops only in the latest stages of growth, even though the final incidence may be high. Similarly, little loss may result even from a disease appearing early in the growing period, if the rate of disease development is slow. Frequent observations make it possible to determine the stage of appearance and rate of development of disease with sufficient accuracy; the rate of development is found by dividing the difference of the percentage area found affected in two successive appraisals by the number of days that elapsed between the latter. However, serious difficulties arise as soon as we attempt to evaluate these two factors in assessing the destructiveness of disease.

The growth of all higher plants may be divided into stages of development which differ widely in their significance for the final productivity of the plant. Freedom from, or a given incidence of, disease may have a profound effect on the yield at one stage of plant development, but may be of little account at another stage. In order to arrive at a true appreciation of the part played by the stage at which the disease appears and by the rate of its development, it would therefore be necessary to "weight" the records made at each stage of plant development according to the relative importance of that stage for the productivity of the plant. But there appears to be no means of finding

accurate quantitative expressions for this purpose, and the coefficients used for such "weighting" can only be arbitrary.

Another aspect of the rôle played by the stage of disease appearance and rate of its development has been stressed by Toomarinson⁷¹. This author has shown experimentally that in oats affected by *Puccinia coronifera* an identical incidence of disease, i.e., the same percentage area of affected tissue, reduces the efficiency of leaves much more when the fungus has passed into the teleutospore stage than when it is still in the uredospore stage. He rightly concludes from this observation that the amount of damage done depends not only on the area affected but also on the time taken by the disease to affect that area.

(b) *Vigour of the host plant.*

The effect of the vigour of the host on the destructiveness of a given incidence of diseases has been pointed out by Goulden & Greaney²⁴ in the case of stem rust of wheat, and there can be no doubt that the vigour of the host may be of deciding importance even where all the other factors are constant. Some diseases are especially destructive on weak plants, while others prefer to attack the most vigorous plants. The vigour of the plant also largely determines its powers of recuperation and of compensating for the loss of diseased tissues. Under this heading mention may also be made of the cumulative effect of a number of different diseases attacking one host simultaneously^{16, 41}. No method is known either of finding quantitative expressions for the host reaction to disease, or of determining the cumulative effects of two diseases, which may differ widely from the sum of the effects produced by each disease separately.

(c) *Intensity of disease.*

Intensity of disease has been defined in the introductory chapter as the destructive energy inherent in the parasitic organism, as distinct from the "destructiveness" of disease which is conditioned by intensity as well as environmental factors. In theory, the intensity of a disease could be determined by considering the loss caused by a given final incidence of disease in relation to the stage of disease appearance, the rate of disease development, and the vigour of the host plants. However, in view of the fact that the latter three factors cannot be quantitatively defined with sufficient accuracy, the intensity of disease cannot in fact be measured.

The above review has shown that the interpretation of a given incidence of disease to indicate the destructiveness of disease can at best yield only a rough approximation to the truth, because most of the factors conditioning destructiveness are not capable of accurate quantitative expression. Most Russian writers^{58, 68} — apparently realising this fact — thus desist, in their instructions for the estimation of plant diseases, from

all attempts to assess destructiveness and limit themselves to an expression of the incidence of disease. Other authors in the U.S.S.R. have suggested diverse means of measuring destructiveness e.g. by cutting out various proportions of tissue^{18, 19}, but none of these appears convincing. Various ways of overcoming the difficulties described above have been proposed in other countries. Ducomet¹⁴ has based his method of estimating losses from cereal stem rust (*Puccinia graminis*) on the fact that some uninfected plants are always present in a field. A comparison of the yield of rusted and non-rusted plants is thus taken to indicate the loss caused by the disease. This method is open to the following objection: very large differences in the state of infection of plants growing under identical conditions invariably arouse suspicion regarding the uniformity of the plant material. In our experience the plants remaining quite free from disease sometimes belong to a different variety of cereal. At any rate, plants which have undergone so important a change in their hereditary make-up as to differ fundamentally from the remaining population in their resistance to disease, cannot be considered to be representative samples of that population in any other respect, and cannot be used to indicate the level of yield that would have been obtained without rust.

Greaney²⁰ has carried out annual repetitions of experiments in which stem rust of wheat was permitted, by various rates of sulphuring, to develop to a number of definite levels of incidence. By means of these trials he was able to determine the destructiveness of a given incidence of disease in each year, and thus to compute the losses caused by the disease according to the data on rust incidence collected in a state survey. The applicability of this method to a wider range of crops and diseases is subject to the following limitations: (a) it can be used only on crops growing under climatic and cultural conditions corresponding closely to those of the experiment; this may be the case in countries such as Canada, where large regions appear to be governed by a reasonably uniform climate. But even then considerable differences in soil fertility and in plant vigour are certain to exist, subtracting from the value of such estimation. (b) The method can be applied only to disease which can be suppressed almost entirely by fungicidal treatments. Unless this is the case, there is no standard by which the loss could be assessed. The fungicidal treatment must, moreover, be free from phytocidal effects, as otherwise the plants kept free from disease may out-yield the diseased plants but little, and wrong conclusions concerning the destructiveness of disease are thus arrived at (Horsfall & Heuberger³⁴). (c) The method is practicable only where a crop is attacked by a single disease; if two or more diseases are present, the control of one of them may render the second more prominent, and in any case the above-mentioned cumulative effect of diseases on the host plant makes it impossible to assess the destructiveness of a single disease if the plants are affected by more than one.

Often, an important aspect of the destructiveness of diseases is their defoliating effect. This point has been dealt with by Palti⁵⁷, who states that, in estimations of olive leaf

spot, "the evaluation of data concerning the shedding of leaves requires a decision whether all the shed leaves found to be infected may be considered to have been shed solely or primarily because of this infection. In the case of olive leaf spot we considered that this question could most probably be answered in the affirmative. Once this was decided, the evaluation of leaf shedding for the purpose of assessing the loss caused by disease on a given tree was simple: every leaf shed is completely lost to the tree and should thus be given marks at least equal to those of the category defining very severe infection."

2. *Effect on the quality of yield*

It is evident from the foregoing paragraphs that the effect of diseases on the size of yield cannot be assessed with any accuracy by visual appraisal of the incidence of disease, except under special circumstances. However, the destructiveness of disease manifests itself in its effect not only on the size, but also on the quality, of yield. If this effect is indirect, as is the effect of rusts on the quality of cereal grains, the position is much the same as it is in the case of the size of yield and little information can be gained by appraisal alone. But in many instances the disease has an immediate effect on the quality of the yield; this is the case in diseases of fruits, ornamental plants, and leaf diseases of crops like tobacco, spinach etc. where the diseased plant organ itself is of economic value. The incidence of disease, i.e., the proportion of affected tissue, may then be interpreted to indicate the destructiveness of the disease.

Wherever the produce is directly affected by disease, a system of grading for the market is usually in operation. The grades frequently group the produce roughly ac-

Category and maximum fruit surface affected	No. of pieces	Maximum area affected x no. of pieces	Disease rating*	Grade (maximum fruit surface affected)	Coefficient of destructiveness (% market value of each grade)	No. of pieces	Coeff. of destructiveness x no. of pieces	% market value**	% destructiveness***
i	ii	iii	iv	v	vi	vii	viii	ix	x
a) no disease=0	50	0	}	I. up to $\frac{1}{10}$	100	120	12000		
b) up to $\frac{1}{10}$	70	7							
c) up to $\frac{1}{3}$	100	33	}	II. up to $\frac{1}{3}$	70	100	7000		
d) up to $\frac{2}{3}$	150	100							
e) up to $\frac{3}{3}$	100	100	}	III. more than $\frac{1}{3}$	30	250	7500		
	470	240							
			51			470	26500	56.4	43.6

* calculated by dividing the total of column iii by the total of column ii, and multiplying the result by 100.

** calculated by dividing the total of column viii by the total of column vii.

*** calculated by subtracting the figure in column ix from 100.

grading to the proportion of diseased tissue. As the number of grades does not usually exceed three or four, most grades will comprise more than one of the categories of infection described above. The relative value of the produce in each grade, under what are considered to be normal marketing conditions, can usually be stated without difficulty. For example, if disease-free or very slightly affected produce (grade A) is valued at 100%, grade B may be put at 70%, and grade C at 30%. These percentages can be used as coefficients of destructiveness. The number of species of produce in each grade is multiplied with the coefficient of that grade. The sum of the figures obtained in this way for each grade is divided by the number of pieces involved, and the resulting figure indicates the relative value of the diseased produce and thus the destructiveness of disease.

The example above demonstrates how the disease rating and the destructiveness of a fruit disease can be computed from the data collected by visual appraisal.

II. USES AND LIMITATIONS OF ESTIMATIONS

The foregoing review leads us to conclude that a fair indication of the incidence of a disease may be obtained by estimation, provided samples are taken correctly. The accuracy of the information gathered by estimation depends (1) on the criterion of estimation; the area of affected plant tissue being preferable in this respect to the number of lesions; (2) on the unit of estimation; small units, such as individual leaves, making for greater accuracy; (3) on the number and size of the samples taken. An element of arbitrariness is introduced into estimation where it is necessary to include in the estimate an expression of the final stages of disease development such as the drying up or premature shedding of leaves; it cannot be decided with certainty by how much a dried-up leaf is more severely affected than a leaf infected on practically its whole area. A similar problem arises where a disease may assume a number of different forms, as quantitative statement of the incidence of disease cannot in general take account of such qualitative differences. However, notwithstanding these limitations, estimations may be regarded as a sufficiently reliable means of measuring plant disease development.

In the interpretation of the estimated incidence of disease to denote the destructiveness of the disease, a distinction must be made between the destructive effect of disease on the size and on the quality of the yield. As regards the effect on the size of yield, emphasis must be laid on the fact that the incidence of disease, as computed by the methods outlined above, indicates only the general proportion of plant tissue affected; it does not convey any information as to which portion or organ of the plant has been attacked. The significance of various organs in determining the size of the final yield frequently differs to a large extent, and for this reason alone the incidence of disease is an inadequate means of assessing the effect of disease on the size of yield. In theory,

this obstacle may be overcome by "weighting" the incidence of disease on the various organs in accordance with the assumed significance of the latter for the size of the yield, but in practice this procedure is involved and highly arbitrary. In addition, the incidence of disease is only one of a number of factors determining the size of the yield, the remaining factors being the stage of host growth at which the disease appears, the rate of disease development, the vigour of the host plant, and the intensity of disease. None of these factors lends itself to accurate quantitative expression and the effect of various levels of incidence of disease on the size of yield can thus only be assessed if all other contributory factors are constant. As this is seldom the case, the computation of the effect of disease on the size of yield according to its estimated incidence will in general result, at best, in rough approximation to the truth, but may also deviate very considerably from the truth.

As regards the effect of disease on the quality of yield, little information can be gained from the estimated incidence of disease, where this effect is indirect, such as the effect of rusts on the quality of cereal grains. However, where the disease has a direct effect on the quality of the produce, as in the case of diseases of fruits, tobacco, flowers etc., the estimated incidence of disease may serve as a basis for a fairly accurate determination of the destructiveness of disease.

In the light of these conclusions the principal uses to which estimations can be applied would appear to be the following :

- i. Estimations represent the sole means of assessing the development of disease in all cases in which the effect of disease on the size of yield cannot be measured, such as
 - (a) where yield records are not available, either because no yield was obtained or because the estimation has covered very large areas (state surveys);
 - (b) where the yield depends primarily not on the disease, but on other factors: thus in fungicidal trials on fruit trees the effect of differential treatments on the yield may not make itself felt until one or several seasons after the treatments have first been applied;
 - (c) not the size of the yield, but its quality is affected either directly or indirectly.

In all these instances, except where the disease directly affects the quality of yield, estimations cannot furnish all the information obtainable by yield measurements, but must be regarded as a different approach to the problem of determining disease development: their results cannot readily replace yield measurements in gauging the destructiveness of disease.

- ii. Where yield data are available, estimations may be employed to advantage in their interpretation. In the simplest case, a consideration of yield records in relation to the estimated incidence of disease may indicate whether differences in the latter are reflected in different levels of yield: i.e., whether the disease causes economic losses. Secondly, wherever the disease represents only one of a number of factors jointly de-

termining the size of yields, the estimation may indicate the relative importance of the disease factor or the conditions under which this factor may become prominent. Special importance attaches to estimations in the case of comparative tests of fungicidal treatments. Apart from their value as a direct measure of fungicidal efficiency, estimations here often represent the only means of determining the phytocidal effect of treatments. These effects cannot be measured directly as they are outwardly apparent only in extreme cases of scorching etc., but they are bound to have repercussions on the level of yield. Careful interpretation of the latter, in the light of estimations of the incidence of disease under each treatment, may then provide the necessary information with regard to the phytocidal action of the material tested. Thus in one of the trials carried out in various parts of Israel⁶² the authors had occasion to observe that lime-sulphur sprays and Bordeaux mixture were almost equally effective in controlling tomato leaf mould (*Cladosporium fulvum*), but that the lime sulphur plots outyielded the Bordeaux mixture plots by a large margin. The fungicidal properties of the sprays being equal, this difference could only be due to their relative phytocidal effects. These results were therefore taken to establish that Bordeaux mixture injured the tomato plants, while lime sulphur spray did not affect them adversely. If the incidence of disease had not been estimated, the difference in yield would have led us to conclude, wrongly, that lime-sulphur sprays are of higher fungicidal efficacy than Bordeaux mixture in controlling the leaf mould, whereas the real difference was concluded to lie in the phytocidal properties of the two sprays.

iii. Estimations may further be used to determine which of the quantitative changes undergone by plants attacked by disease may be considered the direct result of the attack, and thus to establish quantitative criteria for measuring disease development. Working with *Helminthosporium sativum*, Greaney & Machacek²⁸ found that the dry weight of wheat plants, but not their total length, was negatively correlated with the estimated incidence of disease, and accordingly used dry weight as a quantitative index of disease development.

We may conclude that the purposes to which estimations of the incidence of disease can be applied are varied and numerous. Although estimation cannot replace yield data in determining the destructive effect of diseases on the size of yield, they may serve as a valuable means for the fuller interpretation of such data, and often represent the only criterion by which disease development can be measured. In addition, estimations may well be used to determine the destructiveness of diseases directly affecting the quality of agricultural produce.

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ON THE PRESENT STATE OF OUR KNOWLEDGE OF THE HERPETO-
FAUNA OF PALESTINE*

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A summary of research on the Reptile Fauna of the Territory between the Mediterranean Sea and the Syrian Desert including the Sinai Peninsula, with special consideration of the area now occupied by the states of Israel and Jordan. About 90 species are briefly reported. The bulk of new data on dispersal and new species concerns material in the Collection of the Hebrew University, Jerusalem. Several dubious or erroneous statements in the older literature are discussed. Since Flower's paper on "The Reptiles and Amphibia of Egypt", approximately 10 new species have been added for this region.

Following the first publications on the Herpetofauna of Palestine by Boettger, Lortet and Günther, the reptiles of this region have been treated by a considerable number of distinguished herpetologists and collectors. Nevertheless, we are still very far from a satisfactory knowledge of the distribution of this group in the western part of the "fertile crescent". Politically, this area is split up into the states of Syria, Lebanon, Israel, Jordan and a province of Egypt (the region bordered on the west by the Suez Canal, including the "Gaza strip" and the Sinai Peninsula). Geographically, it forms a well-defined entity, bordered in the West by the Mediterranean and the Gulf of Suez, in the East by the Syrio-Arabian desert and in the South by the Red Sea.

The diversity of biotopes in this relatively restricted area is indeed remarkable: along the Mediterranean coast there are coastal dunes in different degrees of fixation, artificially watered plains and swamps; but there are also regions of Mediterranean forest near the coast and — at higher altitudes — even at a considerable distance from the sea. This forest is, in part, well preserved; other parts survive in different degrees of reduction, some of which is caused by man; and in others, there is almost complete annihilation. The greater part of the area is characterized by a diversity of semi-arid and arid landscapes ranging from steppe to desert. This diversity is paralleled by wide

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differences in the annual rainfall, ranging from something like 1680 mm. per annum to practically nil (50 mm). The higher levels have, generally speaking, the large amount of rain, while the eastern and southern parts of the region receive the least and show the different types of desert landscapes in various gradations.

Among the earlier authors dealing with the herpetofauna of a major part of this region, special tribute should be paid to Canon Tristram, who, in his splendid work "Flora and Fauna of Western Palestine"¹⁹, concentrates the data gained from the earlier works of Loret and Böttger together with the material collected by himself and determined by Günther. In 1933, Flower⁸ published his paper on the Reptiles of Egypt, combining his rich experience in this field with the results reported in Anderson's monograph (1898) on the same subject. Flower's paper is of special interest for us, because he takes into account our whole region, especially Sinai, Palestine and Transjordan; the remaining part of the area is briefly summarized as "Syria". He fully uses the considerable quantity of more recent literature as well as data of several collectors in Palestine proper (during World War I) and the results of his travels throughout Egypt and Sinai. Since the appearance of Flower's paper, the author and a considerable number of collaborators have succeeded in concentrating a fairly rich collection of reptiles in the premises of the Hebrew University in Jerusalem. It appears worthwhile, therefore, to give a short account of this field of investigation during the last two decades, specially since a considerable number of recent publications must be taken into consideration. Moreover, Tristram's data were taken into account by Flower only in part, while Werner²², in 1939 subjected them to a revision for "Syria" (and the Lebanon) only. Our present more comprehensive knowledge of the fauna of Israel and Jordan, based on a collecting activity of many years, enables us to check the series of Tristram's data and to test their validity.

The least known region is Transjordan, for, since Tristram's journeys, this area has been investigated only by Festa (results published by Peracca¹⁵), Philipps (Barbour's paper 1914) and an Expedition of the Field Museum of Nat. Hist. (results published by Schmidt¹⁶). The author (1946) also contributed a little to our incomplete knowledge of this area, filling in some gaps concerning the faunal differences between the Levant countries and Iraq and settling some questions as to important boundaries of distribution. The eastern part of Transjordan is almost unknown, though some work has been done on the western part and the South (Wadi Araba and the Aqaba region).

The whole of the data will be treated in systematic sequence, giving for each group the references in Tristram, Flower and the most recent literature, and the results of our own investigations. As a supplement, a revised list of the reptiles occurring in our area will be added, limiting its scope to the regions belonging to the states of Israel and Jordan, but including the "Gaza strip".

It must be emphasized that Tristram's "Palestine" does not agree with the geogr-

phic conception of this area which was en vogue until 1948. Tristram's Palestine comprises the region occupied today by the states of Israel and Jordan (partly) as well as the southern parts of the states of the Lebanon and Syria. He did not visit the eastern parts of Transjordan.

Testudinata

Tristram mentions for "Palestine" the following species: *Testudo ibera* Pallas (= *T. graeca* L.); *Testudo kleinmani* Lortet (= *T. leithii* Günther); *Emys caspica* Gmelin (= *Clemmys caspica* Gmelin); *Emys europaea* D.&B.; *Trionyx aegyptiacus* Geoffr. = *triongis* Forskal; *Chelonia caretta* L. (= *Caretta caretta* L.); *Chelone viridis* Schneider (= *Chelonia mydas* L.).

Flower confirms the general occurrence of *Testudo graeca*, but he found *T. leithii* in northern Sinai only; he thinks that Tristram's "kleinmanni" is a smaller and lighter coloured race of *graeca*. This form has been called *T. graeca floweri* by Bodenheimer⁸ (vide also Mertens¹²) and should occur, according to Tristram, in the region between Hebron and Beersheba, and south of the Dead Sea. Flower also confirms the frequent occurrence of *Clemmys caspica rivulata* Valenciennes in Palestine and Syria. He does not comment on Tristram's data concerning *Emys europaea*, which may derive from a rather vague remark in Lortet (1883, p. 189), who saw them playing in the Sea of Galilee "où elle atteint de grandes dimensions". *Trionyx triunguis* is, according to Flower, only a sporadic, occasional immigrant into the coastal rivers of the Levant coast, being transported by means of the Nile floods which force huge quantities of water along the Mediterranean coast in a northerly direction. Apart from the occurrence of the two species of sea turtles mentioned above, *Eretmochelys imbricata* is added for the Red Sea. (The possible occurrence of *Dermochelys coriacea* should be taken into consideration, see Flower, p. 752).

The collection of the H.U. contains specimens of *Testudo graeca ibera* from both Palestine and Transjordan (vicinity of Jerash); we may add the localities mentioned by Werner²² and earlier workers (ibid.) from Syria and Lebanon. The H.U. Collection has no specimens of *Testudo graeca floweri* or of *T. leithii*. There is no doubt that Lortet's "*Cistudo europaea*" should be omitted from the faunal list of our region, but *Clemmys caspica rivulata* is very common throughout the area in the adequate biotopes. Flower is wrong, however, concerning the sporadic re-immigration of *Trionyx triunguis* from the Nile system into the coastal rivers of the Levant coast. We have, from the river Kishon in Northern Israel to the river Yarkon (Auja) near Tel Aviv, specimens of very different sizes — even very young ones — and we got a batch of eggs from the neighbourhood of Kfar Vitkin, approximately halfway between the above-mentioned localities. We may add that this species has been found in quaternary deposits in Palestine (Bate³) and — near Tel Aviv — in the excavations of Tel Kassile

(1200—800 B.C.E.). It may be assumed that the species is equally well established in the localities further to the North, e.g., Litani, Nahr el Kelb, Lake of Antiochia (we have two very large specimens from this Lake). It was impossible to ascertain the correctness of Siebenrock's (1913) statement about the occurrence of *Trionyx euphratica* in Lake Tiberias; there is, however, a specimen bearing this label in the Vienna Museum!* We have no other data on soft turtles from the Jordan river system, quite in accordance with Tristram's statement. As to sea turtles, *Chelonia mydas* is considerably rarer than *Caretta caretta*; we know of no record of a *Dermochelys* from the Mediterranean coast of Palestine; there is in our collection a head of *Eretmochelys imbricata* from the Gulf of Aqaba.

Crocodylia

Since Böttger's report (1880) on the occurrence of *Crocodylus niloticus* in the freshwater swamps of Kabara (Nahr Zerka near Benyamina), which was restated and confirmed by Tristram, the locality "Zerka" has caused some confusion, because there is a river of the same name in Transjordan. Thus, Gadow ("Reptiles," p. 461) writes of the occurrence of the Nile crocodile in "an eastern tributary of the Jordan", namely, this "second Zerka". Since the year 1902 no other specimens have been recorded from the original locality. In the meantime, the swamp has been drained and all that remains at present is a very small swamp near the spring of the Zerka river, which is now confined to a narrow controlled bed. As a parallel to the case of *Trionyx*, quarternary remains of the crocodile have been identified by Miss Bate³ from a locality not very far from the last refuge of this species in Palestine. A true, long-established colony, and not a sporadic, individual immigration, may, therefore, be presumed for this reptile also. The present local conditions preclude any possibility of a survival of the species at this spot.

SAURIA

Gekkonidae

According to Tristram, the following species live in Palestine: *Stenodactylus guttatus* Cuv. (= *sthenodactylus* Licht.) (north of the Dead Sea); *Gymnodactylus geckoïdes* Spix (Carmel); *Gymnodactylus kotschy* Steind. (Haifa, Beirut); *Hemidactylus verruculatus* Cuv. = *turcica* L. (common in every part of Palestine); *Ptyodactylus hasselquistii* Schneid. = *lobatus* Geoffr. (every part of Palestine).

In this series, *Gymnodactylus geckoïdes* Spix is a synonym of *kotschy*, which is represented in our area by the ssp. *orientalis* Stěpánek¹⁸.

With the appearance of Flower's paper, this list could be enriched by the following

* See Addenda No. 1.

species: 1. *Stenodactylus petrii* Anderson (= *elimensis* Barbour) from Sinai only; 2. *Tropicolotes steudneri* Peters from Sinai; 3. *Tropicolotes nattereri* Steind. from East Sinai (probably not a "good" species, according to Flower); 4. *Gymnodactylus scaber* Heyden; this easily transferable species has been recorded from Tor (Sinai); 5. *Tarentola mauritanica* (L.) from Sinai; 6. from the same region, the Arabian species *Ceramodactylus doriae* Blandford is mentioned (fide Boulenger). All five species mentioned by Tristram are recorded from Sinai also. As species, not seen by Flower but mentioned by Anderson from Egypt, *Bunopus blanfordii* Strauch (for Egypt doubtful, vide Loveridge¹¹; specimen from Aqaba in British Museum) should be added; the possibility of the occurrence of *Pristurus flavipunctatus* is admitted. Boulenger's *Hemidactylus sinaiticus* is not acknowledged even as a variety of *turcicus* — later authors (esp. Parker¹⁴, Loveridge¹¹ retain the Sinai form as a "good" species. An easily distinguishable form of *Ptyodactylus hasselquistii* (var. *sancti-montis* Barbour, from the Hermon area) should be added to this considerable list. We can see at a glance that the "new" species mostly inhabit the Sinai region.

From a review of the most recent literature and our own additions, the following items should be added:

Bunopus crassicauda Nikolsky has been found at Djebel Amri, N. East Syria. *Bunopus tuberculatus* Blandford has been mentioned by Schmidt (from Damesin's Camp, Syria), by Angel (Deir-ez-Zor, Syria), by Haas (manuscript: Wadi Menajeh, S. Palest.). This species, therefore, extends its range very far along the Syrian desert in a southward direction from its main habitat, southern Persia and Baluchistan*.

Tropicolotes steudneri has been mentioned (Haas⁹), from the region west of the Dead Sea, and later from the Negev (Wadi Fukra, S. Palest.). Loveridge: Sinai.

A new species, *Stenodactylus grandiceps* Haas, has been recorded from Transjordan (60 km. south of Amman) and from Addaye (Mossul area, Iraq) Haas, manuscript).

Flower's suggestion concerning the possibility of an occurrence of *Pristurus* is partly confirmed by the occurrence of a small variety, *P. flavipunctatus guweirensis* Haas, in the Nubian sandstone hills north of Guweira (Transjordan).

Ceramodactylus doriae has been found in the southern part of the Wadi Araba. This indicates that the range of the species extends from Sinai in a north-easterly direction.

Angel found *Gymnodactylus scaber* in Abu Kemal, N. E. Syria.

Hemidactylus flaviviridis Rüpp. has been recorded by Anderson from Suez; this record has no special zoo-geographical value as this species may easily have been transferred by ship transports. Similarly, Loveridge¹¹ mentions *Tarentola annularis* (L.) from Sinai. As stated above, Stěpánek described the Palestinian specimens of *Gymnodactylus kotschyi* as subspecies *orientalis* (1937) and subspecies *syriaca* (without locality, ibid.).

* See Addendum No 2.

Ptyodactylus hasselquistii sancti-montis Barbour 1914 was earlier described simultaneously by Peracca¹⁵ as *var. syriacus* and corresponds, according to Loveridge¹⁶, to the ssp. *puisieuxi* Boutan. We found this form not only in Jerash (Transjordan confirming Peracca), at the foot of Mt. Hermon on Israel soil but also in a coherent area in Galilee. In my opinion there are no transitional forms between the two typical *hasselquistii* populations and the striking difference in many morphological details and general habitus warrants the establishment of this group as a clear-cut true species of *Ptyodactylus*. I propose the specific name *puisieuxi*.

Comparing the newest additions with Flower's list, it becomes clear that a number of species recorded by this author from Sinai penetrate into Palestine proper: *Tropidocolotes steudneri* goes very far to the North; *Bunopus tuberculatus* and *Cnemidophorus doriae* penetrate only up to the W. Araba and its tributary wadis.

To sum up, some 14-16 species are known, so far, from the whole region considered in this paper: among them there are a number of primitive species lacking adhesive devices on the fingers.

Agamidae

Tristram gives *Trapelus sinaiticus* = *Agama sinaitica* Hevden for the region of the Dead Sea; *Trapelus ruderatus* Oliv. = *A. ruderata* Ol. for "most parts of Palestine". *Stellio cordylina* Lam. = *Agama stellio* L.: "common"; *Uromastix spinosa* Merrem = *aegyptia* Forsk. "Southern desert of Judea" and *Uromastix ornatus* Rüpp. "Southern desert".

The rather generalized localities for *A. ruderata* give no clear hint as to whether *A. ruderata* or *pallida* is the species in point, or both species, which are often considered as subspecies only (vide, e.g., Wetstein, 1928). Flower, however, considers both forms as "good" species and stresses the uncertainty concerning the northern boundary of *pallida*, which should cross Palestine and Transjordan. He considers both forms as exclusive of each other and mentions *ruderata* from Syria only; *A. pallida* is known to him from Syria and southern Palestine. He confirms Tristram in stating that *A. stellio* is recorded from Syria, Transjordan, Palestine and Sinai (there from southern Palestine and Sinai). It is a pity that he gives no satisfactory descriptions of his three forms (subspecies or geographic races of *stellio*), as we in Palestine meet several geographical types which are easily distinguishable in colour as well as structure. He mentions a dull-coloured form from Alexandria, a darker and bigger form from the granite mountains in south Sinai, and a bright type of medium size from northern Sinai and Palestine. See infra. As an addition, we should mention *Agama nigrata* D.&B. = *maculata* Anderson from Sinai and southern Palestine. There is a doubtful record of *A. spinosa* Gray from Sinai. *Uromastix ornatus* Hevden is stated to be found in Sinai (Werner [1893], Anderson [1896]); *U. aegyptia*, in Sinai; *U. saurastriatus*, in southern

Sinai. Flower does not mention Tristram's statement concerning the occurrence of *ornatus* and *aegyptia* in the "Southern Desert" of Palestine.

As to local races (or subspecies) of *Agama stellio*, we should mention in the first place the black form from Transjordan lava fields, described by Parker¹⁴ as *A. stellio picea*. We are under the impression that the Palestine-Transjordan-Sinai region is inhabited by a series of other easily distinguishable forms: specimens from the northern half of the Transjordanian high plateau (partly covered by Mediterranean wood) are rather dark, even blackish, and have blue patches on the sides of the body; they are quite different from specimens from Palestine in which buff, yellow and brown-greyish hues predominate and which show yellow to orange patches on the back. Another, very big type, in which a brick-red colour predominates, lives in the Negev (S. Palestine). There seem to be some differences also in the pholidosis and size between this and the forms previously mentioned. A full description of this third type will be published shortly.

Flower's *A. savignyi* seems to be identical with Wettstein's (1928) *sanguinolenta isolepis* Blgr.* This is the only species restricted to sandy soil in the Negev, whereas *pallida* is restricted to more loamy and gravelly steppe areas. *Sinaita*, on the other hand, is a characteristic rock-lizard; *stellio*, while also common on rocks, does not seem to be particular in the choice of its biotope, but avoids extremely arid areas. Both species are very often seen perched on prominent boulders or rocks. From the eastern part of Transjordan, Schmidt¹⁶ mentions *Agama persica* Blandford.

Some confusion seems to prevail concerning the species *A. pallida* and *A. rudrata* owing to the fact that even the populations found in the region of Palestine and Transjordan show a wide degree of variation in size and "spinosity". Collecting along the Track of the Pilgrims in Transjordan, one is impressed by the gradual decrease in size of the specimens from North to South; specimens from southern Palestine never reach the size of those caught south of Amman (Wadi Dhoba'i and other places). The picture is further complicated by the presence of very spiny specimens at some distance south of Amman, where the road to Madaba forks off, bearing a certain resemblance to *rudrata*. With regard, however, to the position of the nostril, which lies exactly at the top of the canthus rostralis, the spiny specimens are intermediate between both species in question**. It may be that both "species" merge gradually somewhere (in northern Transjordan). While the lower Jordan valley harbours many reptiles having elsewhere a more southern range, *pallida* does not penetrate into this area.

True *Agama rudrata* are recorded from Syria (Homs, Tel Abiad) by Angel² and by Schmidt¹⁶ from eastern Transjordan (Umm Muwal). Werner²², assigning full specific rank to both, thinks that Peracca's *pallida* from Damascus is probably a

* See Addendum No. 3.

** The Brit. Mus. N.H. Collection contains such a specimen, labelled as *A. rudrata*.

runderata, as this region should be the approximate boundary between the northern "species" *runderata* and the southern *pallida*. But this border-line cannot be correct, since Angel records *pallida* from a place as far north as Palmyra (also specimen in H.U. Collection) and Schmidt a *runderata* as far south as his locality in Transjordan. We may be right, therefore, in assuming that both forms intergaded over a ragged borderline, while pockets of the typical species exist here and there.

Uromastix aegyptius is found rather frequently in the Wadi Araba from the southern end of the Dead Sea to the Gulf of Aqaba, mainly on slopes covered by boulders, and also high on the western slopes of the Araba (Maaleh ha-Aqrabim, east of Kurnub). We have no records of this species being found north of the Dead Sea.

Uromastix ornatus, known from Sinai, has not been recorded from Palestine since Tristram's time. There is the very doubtful quotation of Boulenger, giving "Syria" as the locality of this species. Werner²² thinks that in fact Palestine may have been the real locality in question. Why should a penetration of this Arabian species into the southern corner of Transjordan or Israel be impossible?

Chamaeleonidae

The only species of our area, *Chamaeleon chamaeleon* (L.) is already reported by Tristram as "very common in every part of the country"; this is rather an overstatement, because the species requires considerable air humidity and density of vegetation, but does not necessarily require trees. At any rate, it cannot survive in steppe or desert, but is fairly common in the adequate biotope.

Chamaeleon africanus approaches our area closely, in the western and central Nile Delta, but does not even enter the Sinai Peninsula (vide Flower).

Scincidae

Tristram's list of Scincoid lizards is so extensive that our knowledge today is not much more advanced than it was in the eighties.

Tristram's list:

Ablepharus pannonicus Licht. = *A. kitaibelii* Bibron & Bory: Haifa.

Scincus officinalis Laur.: Syria.

Euprepes fellowsii Gray = *Mabuya septemtaeniata* Reuss; "from Dan to Beersheba". (*Euprepes fellowsii* Günther = *Mabuya vittata* Olivier, [fide Boulenger]. As *M. septemtaeniata* Reuss is absent in Palestine and *vittata* common, a lapsus calami, concerning the author's name, is possible).

Euprepes septemtaeniatus Reuss = *M. septemtaeniata* Reuss: Syria, Lebanon.

Euprepes savignyi Audouin = *Mabuya quinquetaeniata* Gray (fide Boulenger) "on the coast".

Euprepes vittatus Oliv. = *Mabuya vittata* Oliv. : Beirut.

Eumeces pavimentatus Geoffr. = *schneideri* Daud. (acc. to Werner *E. schneideri* var. *pavimentatus*); "rough ground near Dead Sea"; on the coast (Lortet); Jerusalem (Simon).

Ophiomorus miliaris Pallas recte : non Pallas sed Günther = *O. latasti* Günther "in various parts of the north".

Gongylus ocellatus Forsk. = *Chalcides ocellata* Forsk. "this lizard swarms in every part of the country, mountain, or deep valley, in dry places among stones".

Seps monodactylus Günther = *Chalcides güntheri* Blgr. : near Nazareth, Lake Huleh, near Hermon; Jaffa, Haifa (Boettger).

Sphaenops capistratus Wagler = *Chalcides sepsoides* Audouin. Jaffa (Boettger).

According to the synonyms used today, *M. septemtaeniata* appears twice in this list (or else *M. vittata* is referred to more than once).

Flower does not mention Tristram's statement about *septemtaeniata*, which is an East African and Arabian species. Strangely enough, he records *M. vittata* for Palestine alone (not for Sinai or other neighbouring areas). He is doubtful about any occurrence of *quinquetaeniata* = *savignyi* in Palestine or Syria, although some animals might have been imported into a harbour area. As no other author since Tristram's time has mentioned or found this species in our area (e.g., Werner), it should be dropped from the faunal list. *Ablepharus kitaibelii* is known to Flower as occurring in Sinai, Palestine, and Syria; *Eumeces schneideri* (var. *syriacus*) in Sinai and different places in Palestine. *Scincus officinalis* (= *stincus*) does not enter Sinai or Palestine from the West, according to our author, but both *Chalcides sepsoides* and *ocellatus* are found there, the latter in Syria also. Concerning *Ophiomorus latastii* (Type spec. from Mt. Hermon), Flower doubts its occurrence in southern Palestine. (He is right; the animal avoids the arid South). *Chalcides güntheri* is, strangely enough, recorded as a Syrian reptile! (see *infra*).

As we can see, Tristram considerably overestimated the number of Scincidae and we have very little to add, instead.

Peracca¹⁵ describes *Ablepharus festae** from Jerash and Es Salt in Transjordan (Schmidt¹⁶; specimens from Jerash in the collection of the H.U.). We found specimens of *Scincus officinalis* (*stincus*) in the Negev (Asluj); therefore an occurrence in Sinai is very probable. The author erroneously reported as *Sc. officinalis* a specimen, not bearing the characteristic dorsal crossbars, which was collected near Guweira (Transjordan). Comparison with specimens from different parts of the Arabian Peninsula shows clearly that this Transjordanian specimen should be referred to the Arabian species group, which is, however, not yet systematically clarified: *S. meccensis*, *arabicus*, *conirostis*, *philbyi* belong to this group. We have no record of *Mabuya quin-*

* See Addendum No. 4.

que- and *septemataeniata* (see below. Werner knows the species *M. vittata* (as do Müller and Wettstein¹³; from Transjordan: H.U.), and *Eumeces schneideri pavimentatus* from Syria and Lebanon. (See also: Angel²; for Transjordan: Barbour [1914], Peracca¹⁵, H.U.).

To summarize the records of the Scincidae, *Chalcides ocellatus* and *Eumeces schneideri* have the widest dispersal in the whole area; *Mabuya vittata* is absent from Sinai(?); *Ablepharus pannonicus* is not recorded from Transjordan(?)*; *Scincus stincus* enters our area probably from the South but should still be found in Sinai. *Chalcides sepsoides*, too, is a southern form, which is limited to the coastal dune strip of southern Palestine (known as far as Caesarea). *Ophiomorus latastei* has a very restricted dispersal in Upper and Lower Galilee and the Jordan Valley to the slopes of Mt. Gilboa (Tirat Zvi) in the South and Mt. Hermon in the North**. Specimens are known also from Mt. Carmel. *Chalcides güntneri*, also, is a northern type, known from the Hermon and from there southwards on Israel soil until we reach a transverse line connecting Jerusalem and Jaffa. We know no localities south of this area of distribution, but an extension into the hills, perhaps reaching the vicinity of Hebron, is very likely, if we consider the ecological and phyto-sociologic conditions (rather high rainfall, Mediterranean type of vegetation).

Lacertidae

Tristram's enumeration of Lacertids is not easy to discuss as many items are very doubtful and many others are obscured by the shifting nomenclature in this group.

His list and some of his remarks are reproduced below:

- (1) *Lacerta viridis* L. "most abundant in every part of the country".
- (2) *Lacerta strigata* Eichwald "not so common as the former".
- (3) *Lacerta judaica* Camerano (= *L. laevis* Gray) "from the Lebanon to Jerusalem, in upper and hilly country".
- (4) *Lacerta laevis* Gray "near Jerusalem, plains of Jericho".
- (5) *Lacerta agilis* L. "every part of the hill country and maritime plains".
- (6) *Zootoca taurica* Pallas "Phoenician plain, all around base of the Lebanon".
- (7) *Zootoca muralis* Laur. "very common in North of Palestine, not observed in the South".
- (8) *Zootoca tristrami* Günther (= *Acanthodactylus tristrami* Boulenger) "Lebanon District".
- (9) *Zootoca deserti* Günther (= *Ac. pardalis* Licht.) "in plains beneath Hermon and the Lebanon".
- (10) *Acanthodactylus scutellatus* Aud. "near Beirut".

* See, however, Addendum No. 4

** One specimen in the BMNH from Waid Heidan east of Dead sea.

- (11) *Acanthodactylus savignyi* Aud. (= *Ac. schreiberi syriacus* Blgr.) "various localities on the coast".
- (12) *Acanthodactylus boskianus* Daud. "in collections at Beirut" (not found by Tristram).
- (13) *Eremias guttulata* Licht. "near Beirut".
- (14) *Mesalina pardalis* Licht. (= *E. guttulata*) "sandy plain near Beersheba".
- (15) *Ophiops elegans* Ménétr. "very common everywhere, except Jordan valley".
- (16) *Ophiops schlueteri* Boettg. "Beirut".

In this list, 1 and 2 (*Lacerta viridis strigata* Eichwald), 3 and 4 (*Lacerta laevis* Gray), 13 and 14 (*Eremias guttulata* Licht.) are synonyms; 15 and 16 are considered today as varieties of *Ophiops elegans* Ménétr., according to Boulenger.

Flower mentions the following *Lacertidae*: for Palestine: *Lacerta viridis strigata* (= *major wolterstorffii* Mertens, Müller and Wettstein¹³) and *laevis* (the latter from Jaffa, Jerusalem and Petra [Transjordan]); for the Lebanon, *L. fraasii* and *kulzeri* (later: *dandfordi kulzeri*; ref. Müller and Wettstein¹³); *Latastia longicaudata* (Reuss) from Sinai; *Acanthodactylus boskiana* (Daudin) var. *asper* probably from Sinai, Palestine (west of the Dead Sea, Gaza, Auja), and Transjordan (Aqaba, Wadi Kerak); *Acanthodactylus pardalis* (Lichtenstein) var. *typica* from Jaffa (Werner 1898): "this locality seems to me very doubtful, as well as the locality "Jerusalem" quoted by Boulenger, but there is no doubt about the locality Beersheba, as this species is restricted to a loess landscape typical for the Negev (southern Palestine); *Acanthodactylus scutellata* (Audouin) is mentioned for Sinai and Palestine (Jaffa and, again, a very improbable locality, Jerusalem; this species is found in the lowland in dunes only, and not at 800 m. above sea level); "three other forms, *tristrami*, *grandis* and *schreiberi* var. *syriacus*, occur in Syria; the first two in the North, the third coming right down into Palestine". *A. robustus* has been recorded by Schmidt (1930) from Transjordan. *Ophiops elegans* Ménétr. is recorded from southern Sinai (Barbour 1914) and widely distributed in Palestine (near the Dead Sea, Jaffa [Werner 1898] and Mt. Hermon); Werner does not discuss the relationship of Boulenger's "varieties" of this species. *Eremias guttulata* Lichtenstein is mentioned for Sinai, Palestine and Transjordan; he considers the varieties *olivieri* and *martini* as individual variations ("at any rate in Egypt") and not as geographical races. (Boulenger⁶ mentions both from Sinai, the typical variety from Palestine). *Eremias rubropunctata* Lichtenstein is recorded from Sinai (central part) only. "The area of distribution of a Punjab species *brevirostris* extends to northern Syria (Boulenger 1921, 1923)." The species *Eremias mucronatus* Blanford (= *brenneri* Blgr.) is doubtfully recorded for Sinai.

Taking into consideration the synonyma in Tristram's list of *Lacertidae*, Flower considerably enlarged our knowledge of this family, which has so many representatives in our area; he does not even discuss three species mentioned by Tristram — doubtless

owing to false determinations — namely: *Lacerta agilis*, *Zootoca taurica*, *Zootoca muralis*. Probably these errors are due to a false interpretation of the relatively newly described species from the Lebanon, *Lacerta danfordi kulzeri* and *L. fraasi*. I cannot, however, find an explanation for the quotation of *Lacerta agilis* (see also Werner [1898]); already Boettger (1878/79) thought that the recorded occurrence of *L. muralis* from Palestine was due to a false determination of *L. laevis*. With regard to the locality references mentioned above, some criticism seems indicated. *Lacerta viridis strigata* (=major wolterstorffii) is met in Israel in areas of Mediterranean woodland only. This species, therefore, has a rather continuous dispersal in the relatively moister areas of Galilee, especially near the northern frontier, and, high up in the hills, some island-like refuges in the Judean Hills (e.g., Aquabella and Deir Abu Ammar west of Jerusalem). *Lacerta laevis* has been found near Jericho, but I think that this isolated atypical occurrence is due to the agency of man (importation by chance into a man-made oasis). Tristram's localities for *Zootoca deserti* seem very improbable to me, as this species has a very densely populated and restricted dispersal in the south Palestinian loess plains. The locality Beirut for *Acanthodactylus scutellatus* is also doubtful; to our knowledge, the northern boundary of this species lies some 50 kms. north of Tel Aviv. It seems very strange, to a Palestinian herpetologist, that Tristram, who so often visited the Dead Sea and Lower Jordan area, did not find the very common lizards of this area, namely *Acanthodactylus boskianus* and *Eremias guttulata*. The locality near Beirut for the latter is quite misleading.

Recent Literature and Data based on our own Observations and Collections.

The Syrian green lizard has been described under different names: *Lacerta viridis strigata* Eichwald seems to be identical with *L. strigata major* Boulenger (Werner²² for Syria and Lebanon), and with *L. major wolterstorffii* Mertens (1933). All known localities are situated in the evergreen Mediterranean forest region and are relatively rich in rainfall and shadow. Outside this centre of distribution in the Lebanon and northern Palestine (apparently harbouring a relatively dense population) there are scattered islands, as far south, perhaps, as Hebron in the Judean hills (see above) but also in Syria (Werner).

Angel² describes a var. *nigra* of *Lacerta laevis* from Beirut and Tartous. Specimens from Palestine are very uniform in coloration: the brown back is not mottled with black (as I saw it in specimens from Syria and in our specimens from Petra). *Lacerta laevis* from northern Transjordan (Jerash), identical in colour with Palestinian specimens, is in the H.U. Collection.

Müller and Wettstein's *Lacerta kulzeri* (1932) has been fully redescribed by the same authors¹³ under the name *L. danfordi kulzeri*. The specimens from Petra (Trans-

jordan) and Shiba (on Mt. Hermon), described by Barbour (1914) as *L. danfordi*, are referred to *L. laevis* by Boulenger: "should be compared with *L. laevis*". Wettstein examined our specimens from Petra and decided to consider them as slightly aberrant *L. laevis*. There are no records from Israel (northern part) of *L. danfordi kulzeri* or of *L. fraasi* (recorded from the Lebanon at altitudes ranging from 1,800—2,300 m.). Perhaps Tristram considered specimens of this lizard as *Zootoca taurica*; the localities, however, "all around the base of the Lebanon and Phoenician plain" do not suit a high mountain inhabitant. We are able to add some interesting new localities for the genus *Acanthodactylus*. In the area west of the Jordan only the following species are found: *A. schreiberi syriacus*, *scutellatus*, *pardalis*, *boskianus asper*. The species *grandis*, *tristrami* and *robustus*, formerly known only from the northern parts of the Syrian desert, have a much wider range.

Specimens of *A. grandis* could be found at localities (Tel Abiad) some 400 km. north-west of the terra typica (see Angel²). The author described specimens from Transjordan (1943, between Hissa and Ma'an); this species has a very extended range along the western border of the Syrian desert.

Angel² describes a smaller north-eastern form of *Acanthodactylus tristrami (orientalis)*, which is recorded by Schmidt¹⁶ from the Syrian "panhandle" (Palmyra-Der-ez-Zor). *Tristrami* has been found by us in Transjordan also.

Since Werner's original description of *A. robustus*²⁰ from the Syrian desert, Schmidt (1930) and Haas⁹ found this species on Transjordan territory. The H.U. collection has a beautiful series of specimens of it, collected by J. Aharoni; unfortunately, instead of a precise locality, only "Syrian desert" was noted. The question of *E. guttulata guttulata* and Boulenger's var. *olivieri* has been discussed by the author elsewhere (manuscript). The "*olivieri*-form" of Transjordan and Palestine should be considered a subspecies and will be described as *olivieri* ssp. *schmidtii*. This subspecies is distinguished from *olivieri* by several well-defined characters in pholidosis as well as in colour*. It may be that Boulenger's "*olivieri*", with its very extended range, is a mixture of several closely related *Eremias* forms. In a number of biotopes in southern Palestine *guttulata* and *olivieri schmidtii* live together, but around the Detad Sea and in the Judean desert, near the Jerusalem-Jericho road and the lower Jordan Valley, *guttulata* only is represented. On the other hand, we found *schmidtii* exclusively in depressions between the dunes near Jaffa on patches of exposed heavy soil.

Eremias brevirostris has been found by Angel² in Haouarine in Syria (for other places in Syria, ranging from Palmyra to Damascus, Werner²²); this species penetrates from Northern Syria southwards right through Transjordan to Aqaba (Haas⁹). We have no knowledge of any localities west of the Wadi Araba. Probably the southward extension along the western margin of the Syrian desert is of relatively recent date,

* See Addendum No.5.

having taken place after the formation of the great rift which the species was unable to cross owing to its very high temperatures and dryness. In Transjordan, the specimens are considerably smaller in the South than in the North.

We have no record of *Eremias mucronata* and *rubropunctata* from Israel and Transjordan, not even from the southern corners of the states.

In the extreme North of our region, in the Amanus, (Schechle : Werner²²), *Latastia cappadocica* has been found; *L. longicaudata*, known from Sinai, has not been found elsewhere since.

Boulenger splits *Ophisops elegans* into a series of "varieties", of which *ehrenbergii*, *schlueteri* and *mizolepis* are recorded from our region. The predominant variety is, (for Transjordan and Israel) *ehrenbergii*; *schlueteri* has been recorded from the northern corner of Israel (Lebanon and Syria) around the Hermon massif; *mizolepis*, from Haifa. Schmidt¹⁶ records *elegans elegans*, also, from Syria and Transjordan. I fully agree with Werner²² in attaching slight value to these "varieties"; they are probably without geographical significance and their characterization is rather vague. In the area of *ehrenbergii* we found, near Gaza, a population whose scale and ventral plates across the middle of the body number less than Boulenger's minimal values — otherwise these specimens conform with the rest. A population of very large specimens with blue markings at the flanks is found around the Huleh Basin. These specimens, however, agree in their pholidosis with *ehrenbergii*. These characters are probably not sufficient for a thorough study of the geographical races which, no doubt, exist in the vast range of this species. This seems fairly evident if we consider that in the H.U. Collection *mizolepis*-forms are represented from regions geographically and ecologically as disparate as Hanita (Northern Israel : terra rossa soil, Mediterranean forest) and the steppe area between Petra and Ma'an in Transjordan (very sparse low-growing vegetation). From the Petra hills "*schlueteri*" specimens, also, could be determined. The taxonomy of this very common small reptile badly needs full revision owing to the fact that it splits into local populations and so often seems to produce corresponding changes from the norm in far distant areas.

Amphisbaenidae

According to Tristram, *Amphisbaena cinerea* (Vaud.) = *Blanus cinereus* Bedriaga, but in fact *B. strauchii* Bedriaga, should occur ("not uncommon") under stones in the plain of Genezareth and in the coastal plain. It has not been possible to confirm this reference since Tristram's time. Boettger mentions the species only from Cyprus and Rhodes. Werner²² saw only a specimen from Northern Syria, "doch scheint *Blanus* nicht über Syrien nach Süden hinauszugehen". Aharoni told the author of specimens he had collected in the Huleh Basin, but specimens are not represented in his collection, now incorporated in the H.U. Collection.

Varanidae

According to Tristram, two species of *Varanidae* live in Palestine, namely: *Psammotaurus scincus* Merrem (= *Varanus griseus* Daud.) in the vicinity of Ein Geddi (west coast of the Dead Sea) and *Monitor niloticus* Geoffr. in the South of the Dead Sea and in the South of the Judean Desert.

Flower records the first species for Sinai, Palestine and Transjordan and states briefly that Tristram's record of *V. niloticus* could not be confirmed. Obviously, Tristram's localities for both species lie within the area inhabited only by the first. In the coastal plain, *V. griseus* is found as far north as Jaffa, but the northern limit in the Rift Valley is unknown. (It is also known, farther in the East, from Mesopotamia). I saw a beautiful specimen in the sandy region east of Kurnub (Negev). The species is not recorded from Syria.

Anguidae

Tristram mentions (fide Müller) the European Glass Snake, *Anguis fragilis* L., as an inhabitant of Palestine, a statement which is, no doubt, an error. *Pseudopus apoda* Pallas = *Ophisaurus apodus* is recorded from Mt. Hermon; Flower gives three localities in Palestine: Wadi Rubin, Judean Hills (2,700 m. above S.L.) and near Nazareth. We have no record of this species south of the Valley of Esdraelon, but it is not rare in Upper and Lower Galilee or in the Emek (an area covered mainly by Mediterranean vegetation). There is no record for Syria in Werner²², but Peracca found this giant glass-snake in Es-Salt (Transjordan), a place with a luxuriant Mediterranean vegetation on the slopes and the bottom of a deep wadi. The southern limit of this species crosses both Palestine and Transjordan, but so far details are not known.

OPHIDIA

Boidae

Eryx jaculus L. has been known from Palestine since Hasselquist's travels (1749-52). It is interesting that Tristram mentions the rapidity of this snake's movements — it is, in fact, rather sluggish. Many authors record this rather common snake from our area: Flower, from Palestine (between Rafa and Gaza) and Syria; Boettger, from Beirut; Günther, from Galilee; Angel, from Tartous and Charagrag; Werner, from Coelesyria (Beka'a) near Baalbek (Boulenger); Schmidt, from the Jordan Valley. Nothing is known of its occurrence in Sinai. In the H.U. Collection we have quite a number of specimens of this remarkably uniform snake. It is mainly confined to the coastal plain, especially common in regions covered by coastal dunes and stretches of the red "Khamra"-soil, and shows a certain preference for citrus groves. Nevertheless, we found specimens also in the Central Negev (Beth Eshel, Dorot), in the Jordan

Valley (Maoz) and in the hills (Rosh Pina, Jerusalem). We have no record from Transjordan, but, as the snake is known from Mesopotamia, it will surely be found in this intermediate region also.

Typhlopidae

Tristram reports both species, *Typhlops syriacus* Jan=*vermicularis* Merrem, and *Onychocephalus simoni* Boettger=*T. simoni* Boettger; the first being described as very common everywhere, the second reported from Jaffa and Caiffa (=Haifa). Almost every author mentions *T. vermicularis*: Lortet (1883) from Syria and Palestine; Flower (1933) from Sinai, Palestine and Syria; Werner (1939), from Damascus, Nisib near Aleppo, Mt. Hermon (1,500 m.) and Amanus; Angel (1936), from Beirut, etc. We have a large collection of this species, which appears to inhabit the whole of Israel with the exception of true deserts; a certain humidity seems to be indispensable to this species, which is regularly found on the surface in late spring (April to June) and later, under stones in the hills. It is found in great numbers in marshy places, e.g., the northern border of the Lake of Galilee and the dried swamps of the coastal area (Benyamina) and the Emek (Ein Harod). The large amount of rainfall in the hills seems to suit the natural requirements of this species which is never found in the driest time of the year. There are no records from Transjordan, but its occurrence in Iraq suggests that it might be found there also, especially in the higher parts of the country.

The distribution of *Typhlops simoni* is rather scattered. First recorded by Boettger from Jaffa and Haifa, Peracca (1894) found this species in Jericho. Our collection (H.U.) has several specimens from the southern shores of Lake Tiberias and Tiberias (whereas *T. vermicularis* is not found there); from the surroundings of Gaza, 30 km. east of Beersheba; from east of Beni Naim (Judean desert); and from Bat Yam near Tel Aviv. The species seems to be limited to Israel and Cisjordan and prefers rather damp localities of lower elevation, even in very hot parts of the country, avoiding the regions of limestone rocks. No records exist so far from Transjordan and the Syrian area.

Leptotyphlopidae (= *Glauconüdae*)

Barbour described (1914) as *Leptotyphlops phillipsi* Barbour a little snake from Petra (Transjordan); this species proved to be synonymous with *L. macrorhynchus* (Jan), known to Boulenger (1893) from Nubia and (?) the Euphrates. In a later publication Boulenger (1920; Journ. Bombay Nat. Hist. Soc. p. 25) confirms this dubious statement (Faleya, Euphrates).

This tiny creature has been found again by Haas (1943), at Ein Harod in the Emek Jezreel. Later, the H.U. Collection received specimens from Dorot in the Negev and from Ein Feshkha on the north-western shore of the Dead Sea. These rather

scattered localities are insufficient for an intimate understanding of the ecological requirements of the species.

A high soil humidity and rather light soil seem to be indispensable for so tiny an animal. It appears to prefer the lower localities of the country and a hot climate. Nothing is known about its occurrence in Syria-Lebanon.

Colubridae aglyphae

According to Tristram, the following species belong to the Fauna of Palestine.

- (1) *Rhynchocalamus melanocephalus* Günther (= *Oligodon melanocephalum* Jan) Lake Huleh, Jericho, Lake Tiberias (whole Jordan Valley).
- (2) *Ablabes coronella* Schlegel = *Contia coronella* Schlegel = *Eirenis lineo-maculata* Schmidt, "every part of the country, Lebanon, Hermon, Huleh, Genesareth, Tyre, Nablus".
- (3) *Ablabes modestus* Martin = (fide Günther) *Eirenis rothii* Jan (an error, see later), the Lebanon, Mt. Hermon.
- (4) *Ablabes fasciatus* Jan = *Eirenis coronella* Schlegel (Schmidt¹⁰), "dry stony places on the hills".
- (5) *Ablabes decemlineatus* Dum. et Bibr. (= *Eirenis decemlineatus* Dum. et Bibr.) Galilee, Plain of Phoenicia, lower Lebanon, Huleh.
- (6) *Ablabes collaris* Ménétr. = *Eirenis collaris* Ménétr., near Beirut.
- (7) *Coronella austriaca* Dum. et Bibr., "near Beirut and elsewhere in Palestine".
- (8) *Coluber aesculapii* = *Elaphe longissima* (Laur.), near Beirut
- (9) *Coluber quadrilineatus* Pall. = (*Elaphe*), northern Palestine.
- (10) *Zamenis diadema* Schl. = *Spalerosophis diadema* Schl. = *Periops parallelus* Geoffr., Phoenician and Philistian plains.
- (11) *Zamenis ventrimaculatus* Gray = (*Coluber*); round the Dead Sea.
- (12) *Zamenis caudaelineatus* Günther = *Coluber nummifer* Reuss = *C. raverigieri* Ménétr.; near Jerusalem, Nazareth, Tyre.
- (13) *Zamenis viridiflavus* Dum. et Bibr. = *Coluber jugularis asianus* Bttg., throughout the country, both in the Jordan Valley and on the hills.
- (14) *Zamenis viridiflavus*, var. *carbonarius* Bonap. = *Coluber jugularis jugularis* L. "warmer parts of the country, Jordan valley, rarer in maritime plains, where the other is much more abundant".
- (15) not in the hills; *Zamenis dahlui* Dum. et Bibr. = *Coluber najadum* Eichwald; in moist, but not in marshy places.
- (16) *Zamenis raverigieri* Ménétr. = *C. raverigieri* Ménétr. Lake Phiala (Birket er-Ram).
- (17) *Zamenis algira* Jan, banks of the rivers Litani, Nahr-el-Kebir and others.

- (18) *Tropidonotus hydrus* Pall. = *Natrix tessellatus* Laur. swarms in lakes and little ponds; especially abundant in Lake Phiala.
- (19) *Tropidonotus tessellatus* Laur. Nahr el Kebir, plains of Genesaret, Sidon.
- (20) *Tropidonotus natrix* Lineé = *Natrix natrix* L., in Palestine (Böttger, Müller, Bedriaga).

This list needs some corrections: Nos. 12 and 16, and also 18 and 19, are synonymous. A number of species have never been mentioned since Tristram, and our improved knowledge of the geographical boundaries of repartition of the species involved enables us to eliminate the following species as highly improbable for our area: *Coronella austriaca*, *Coluber aesculapii*, *Coluber quadrilineatus*, *Zamenis algira*. According to Werner, Boettger mentions *Elaphe situla* from Beirut. This record appears highly improbable (see Werner 1896/97 and 1939). At least for Palestine, *Coluber jugularis jugularis* only, has been recorded by later authors. As the juvenile coloration of this species changes to black, juvenile specimens were probably mistaken for *C. j. asianus*.

Turning now to Flower's list, we see that he was able to add a considerable number of species to Tristram's thirteen aglyphous Colubrids.

"*Natrix natrix* has been reported from Palestine, but its occurrence there is doubtful". Barbour described *N. tessellata* as occurring in Sinai; Flower found this species entering the eastern Nile Delta. It exists throughout Palestine and Syria.

Flower refers to eight species of *Coluber* for Palestine-Syria-Egypt. From this number, *florulentus* should be excluded from our area; *jugularis* and *naiadum* are not found in Egypt.

His list of the genus *Coluber* follows:

C. jugularis jugularis L. Palestine (Jebnah, near Ramle; near Jericho).

C. najadum Eichw.: Palestine (Sarona), Syria, fide Werner, Barbour).

C. rhodorhachis Jan: Palestine, Syria(?), Sinai (W. Feiran).

C. ventromaculatus Gray: Palestine, perhaps Sinai. This statement is erroneous, as the author's remarks concerning coloration of a specimen caught between Gaza and the Egyptian frontier (as it was before 1948) show clearly that it should be referred to the next species.

C. rogersi Anderson: Palestine and Sinai (Wadi el Gedeirat near Kossaima; Maghara hills; Sudr el Haitan; Ras el Jaifi).

C. elegantissimus Günther: our knowledge of this species is based on two specimens only; the type being from "Mountains east of el Muwavlah, Midian (Hedjas); Aqaba, or on way from Sinai to Aqaba" (Hart).

C. ravergieri ravergieri Ménétr.: probably in Northern Syria only.

C. ravergieri nummifer Reuss: Southern Syria(?), Palestine (Jerusalem; Nazareth; Haifa; Tyre; Sidon; Jaffa); Transjordan (Kerak), Sinai (W. Feiran, Barbour 1914).

Spalerosophis diadema Schlegel: Sinai (Kossaima), Palestine (Aqaba to the Dead Sea: Hart 1891; Gaza).

Lytorhynchus diadema Dum. et Bibr. Strangely enough, Tristram does not mention this rather common snake. Sinai (Mahadat; Mohammadia); Palestine (Gaza, Ramle).

Oligodon melanocephalum Jan: occurrence in Sinai very doubtful (Hart's specimen, labelled "Sinaitic Peninsula" is in fact from Petra, Transjordan), Palestine (Wadi Guzee), Syria.

Contia (= *Eirenis*) *fasciatus* Jan = *Eirenis coronella* Schlegel (Schmidt¹⁶). Sinai (Gebel Dhalfa, North Sinai), Palestine, Syria.

Contia (= *Eirenis*) *coronella* Schlegel = *E. lineomaculata* Schmidt: Sinai ([Anderson 1904]; St. Catherina Monastery [Barbour 1914]); Palestine (Jordan Valley), Petra [Barbour 1914], Syria. Barbour's data, however, have to be referred to *Eirenis coronella* Schlegel; this author merged the two species, on obvious error!

The following species of *Contia* are unknown from Egypt and Sinai, but occur in Palestine: *C. decemlineata*, *collaris*, *modesta*, *rothii*.

This short survey of the *Aglyphae* shows that there exist some unsettled issues, which render a comparison of Tristram's and Flower's lists a difficult matter. The main difficulties lie in the doubtful validity of the determination of *Coluber ventromaculatus* (in both authors) as well as in the uncertain systematics of the genus *Contia* (*Eirenis*). Perusing Boulenger's Catalogue of Snakes, I found that Günther's *Zamenis ventromaculatus* (probably Tristram's specimen from the Dead Sea) is in fact a *Zamenis rhodorhachis* (vide Günther 1864). Flower, again, refers a specimen from southern Palestine to *ventromaculatus* and concludes that possibly the species penetrated into Sinai. As the coloration mentioned is quite atypical for this species but typical of *Coluber rogersi*, the slightly higher number of ventrals (207) as compared with Werner's data (in "*Colubridae*": 197—201) is not sufficient to exclude his specimen from this species. In the collection of the H.U. there is also one specimen, from Wadi Dhaba'i (Transjordan), with 207 ventrals. So we should revise the data for *rogersi* given by Werner²². Corkill's photographs⁷ show clearly the completely different coloration of his true *ventromaculatus*-specimens from Iraq. In this connection we may refer to Angel², who states that in his specimen, also, the dorsal patches are much wider than the bright intervals (he, too, refers it to *ventromaculatus*): I think that he is dealing with a true *rogersi* also. We may, therefore, assume that the upper limit for the ventralia is higher than that indicated in the first description of this species.

Concerning the rather confused state of *Contia decemlineata-modesta-collaris*, the following remarks may be of some use. Specimens from Lebanon, the Hermon (Ferzöl), and the Amanus are referred by Werner to *C. modesta*. (Boulenger's specimen: Voy. Gadeau de Kerville, p. 55, (1923), is referred to *Contia collaris* Ménétr.). Werner's *Contia modesta* is, therefore, a snake with 17 scale-rows and is closely related to *Contia decemlineata* Dum. et Bibr., from which it is distinguished by frontals at least

* See Addendum No. 6.

twice as long as they are broad (in the other at highest $1\frac{2}{3}$ as long as broad). All the specimens from Palestine and Transjordan in our collections are true *decemlineata*. There is no doubt that Boulenger's (1894) *Contia collaris* is a mixture of *C. collaris* Ménétr., a small snake with 15 scale-rows, and *C. modesta* Martin, a larger snake with 17 scale-rows*. I think that Boulenger's "mixture" is due to a statement by Günther, who maintains that *Eirenis rothii* Jan is not specifically distinct from *Ablabes modestus* Martin. For this reason, we have some doubts concerning Tristram's localities for this latter species: there are no references in the British Museum Catalogue indicating Tristram as collector of any specimen of Boulenger's mixed *Contia collaris-modesta*. In the appendix to the Catalogue of Snakes mention is made (III. p. 642) of a specimen from Mt. Hermon (Turin Mus.); as it has 17 scale-rows, it almost certainly refers to *C. modesta*; therefore, one of Tristram's localities might be confirmed again, but Peracca¹⁵ gives, under the name *Homalosoma modestus*, snakes with both 15 and 17 scale-rows again, almost certainly a mixture (locality: Hermon area, Ferzol). Schmidt's¹⁶ *Eirenis collaris* Ménétr. from the Jordan Valley resembles the Palestinian *Eirenis rothii* Jan in coloration, but has rather different numbers of ventrals and subcaudals. (Corkill for *collaris*: V. 170—200, Sc. 55—75; data of 5 specimens of *rothii* [H.U.-C.] show ventrals: 166—187, Sc.: 46—54. Peracca's specimen from Es Salt (Transjordan) is considered as *E. collaris*, owing to its high number of subcaudals (V. 187, Sc. 60). Boulenger records, for *rothii*, V. 159—183, Sc. 40—53. We see, from this as well as other evidence, that both species are closely related, or, possibly, merging locally. The higher number of subcaudals in *collaris* seems to be the main difference between them. The H.U. collection contains true *rothii* from Jerash (Transjordan)*.

Summarizing these complicated data, we may stress again that *Coluber ventromaculatus* Gray probably does not enter our region (but is recorded from Iraq [see Corkill]); that *Contia rothii* and *collaris* (if they are in fact clearly distinguishable species) co-exist, perhaps in Transjordan and other places; but that, at least in Palestine, *rothii* is the characteristic species. (But see Schmidt's specimen with the rather inexact locality "Jordan Valley", and Flower's specimen from Jericho [p. 816/17]). From Iraq, only the species *collaris* is recorded, but in Transjordan and Syria both species co-exist.

Natrix tessellata is the only aquatic snake recorded so far from Palestine and Transjordan; concerning the question of the occurrence of *N. natrix*, Werner²² reports f. *bilineata* from the Lebanon and Syria and thinks that this species does not exist farther south than Beirut. The same author mentions both *Coluber jugularis jugularis* and *asianus* for Syria and the Lebanon. In spite of Tristram's statement, which agrees with that of Werner for Syria, I am convinced that, at a certain size, all individuals of this species turn black and should therefore be referred to *jugularis* only. The

* See Addendum No. 6.

size at which this blackening starts is approximately one metre; we have several specimens showing the gradual darkening of the juvenile colour pattern and not one, above a certain size group, shows even traces of the former coloration. Our biggest specimens are nearly 2,500 mm. long. Angel records the species from Syria (Hama); the H.U. Collection has specimens from Jerash (Transjordan).

Coluber najadum is known so far from Palestine, Syria, the Lebanon, and (Barbour 1914) from Transjordan (Kerak). Tristram is certainly not correct in limiting this species to the lowlands; we have several specimens from the hills (e.g., Jerusalem); this snake is by no means rare.

Two species of desert racers are widely distributed in the Negev and in the lower Jordan Valley: *Coluber rhodorhachis* and *rogersi*. The H.U. Collection has a very fine specimen of *rhodorhachis* from the South end of the Dead Sea. Werner does not mention this species from Syria. In considering the question of the validity of *C. ventromaculatus*, quoted by Flower from southern Palestine and by Angel from northern Syria (Palmyra), I concluded that both cases should be referred to *rogersi* (see below); the H.U. Collection has identical specimens with the same high numbers of ventrals from Transjordan, and others from different parts of the Negev. We did not get any specimen of the probably Arabian species, *elegantissimus* — there are no records of any specimens being caught since those mentioned by Flower.

Concerning the geographical boundary between *Coluber nummifer* Reuss and the form *ravergieri* Ménétr., Werner states that the borderline in Syria lies somewhere between the Lebanon and Amanus, *ravergieri* having been recorded in the Amanus and Asia Minor; Angel found typical *nummifer* in Beirut, Hama and Homs (Lebanon; Syria); from Hama he describes a new form *pallaryi*. *Nummifer* has a wide distribution in Palestine but this species avoids the drier parts, especially the South, of the country. In Jerusalem (800 m.) this species is perhaps the commonest *Coluber*.

In contrast to the latter species, *Spalerosophis diadema* is very thermophilous and, in Palestine, is met in the southern Jordan Valley and in the Negev (H.U. Collection). We found this species also in Transjordan (W. Dhoba'i) and Angel reports it from as far north as Palmyra (Syria). Specimens from Transjordan are remarkably different from the Palestinian ones and are probably of subspecific value. Corkill also describes two different forms from Iraq; there probably exists, therefore, an unbroken series of forms from Palestine, through Transjordan and Iraq, to Iran. All these forms would repay a thorough study of the whole "Formenkreis"; for the moment we have not enough material to undertake such a task, even for Palestine and Transjordan only.

We have now to consider the possibility that two different types of *Lytorhynchus diadema* exist in Palestine. Specimens from the coastal plain correspond to the Egyptian population in having a stouter habitus and a lower number of dorsal markings than the specimens from the drier hinterland in the Negev. We have no records of

this species from Syria or the Lebanon, or, strangely enough, from Transjordan either, but the species is recorded from Sinai, Iraq (Corkill: the Syrian Desert at Rutba), and Central Arabia (manuscript); its occurrence in Syria and Transjordan is, therefore, not improbable.

According to Angel, Wettstein and Werner, *Oligodon melanocephalus* is known from the Lebanon and Syria. In Palestine this form is widely distributed, but it avoids regions of extreme dryness.

The following species of *Contia* (= *Eirenis*) have been described, so far, from Israel: the commonest are *C. rothii* and *decemlineata* (especially in the cultivated coastal plain and in the hills of Judea); *C. lineomaculata* and *coronella* (nomenclature after Schmidt¹⁶) avoid each other almost entirely — but in certain parts of the Judean desert and the Negev they may be found together. *Coronella* is the more aridophilous form and has its maximum frequency especially in the South of Transjordan, the Negev and Sinai. The species *lineomaculata* is somewhat common in the Judean desert, but also occurs fairly frequently in the moister parts of Palestine, especially in country covered with boulders and a sparse vegetation (e.g., in deforested localities on the plateau of Mt. Carmel; near Jerusalem). *Contia collaris* has been recorded twice from Israel by Flower (1932), from Jericho, by Schmidt¹⁶ from the Jordan Valley, and by Peracca¹⁵ from Transjordan (Es Salt). We have no records of *C. modesta* from Palestine proper (See Addendum No. 6).

Summarizing the newer literature and excluding Israel we may compile the following list of dispersal areas:

Contia rothii: the Lebanon (Werner); Transjordan (H.U. Collection): not Sinai.

Contia coronella Schlegel: Syria (Schmidt), Transjordan (H.U. Collection and others), Sinai (Barbour), not the Lebanon.

The H.U. Collection has a specimen from Transjordan which seems to correspond to Schmidt's *var. fraseri* (type from Rutba, Iraq).

Contia decemlineata: Syria (Angel, Werner); the Lebanon (Werner); Transjordan (H.U. Collection), not Sinai.

Contia lineomaculata: Syria (Angel); the Lebanon (Werner); we have no references from Transjordan; Barbour's specimens from Sinai should be referred to *coronella* Schlegel, because they have 15 scale-rows and the ventral counts are too high. I do not think that this species enters Sinai. Corkill records 15—19 scale-rows; for his *Contia coronella* (= *lineomaculata* Schmidt). He evidently confuses *lineomaculata* and *coronella* (= *fasciata* auct.); therefore, an occurrence in Transjordan is possible, but not yet proved.

Contia modesta: the Lebanon (Werner); and (Peracca) also in Syria (Hermon area); not from Palestine or Sinai.

Contia collaris: Palestine (Flower, Schmidt) both localities probably in "Jordania";

Transjordan (Peracca; the species is also known from Iraq, vide Corkill): not from Syria and the Lebanon. The H.U. Collection has many *C. rothii* from Palestine; several in the large series reach the lower scale margin assigned to *collaris*.

Colubridae opisthoglyphae

Tristram knows the following species from Palestine:

Micrelaps muelleri Boettger (hill country of Judea and Galilee: type from Jerusalem; after Lortet: Lattakieh).

Coelopeltis lacertina Wagl. = *Malpolon monspessulanum* Herrmann: near Jerusalem; Galilee; round Lake Tiberias and Lake Huleh (Lortet).

Psammophis moniliger Daud. = *schokari* Forsk.: Tiberias; Solomon's Pools near Bethlehem (Lortet).

Tachymenis vivax Fitz. = *Tarbophis savignyi* Boulenger (= *fallax syriacus* Boettger); Jerusalem, Tabor, Tiberias. "Syria".

Flower briefly mentions *Micrelaps muelleri* for Palestine; *Tarbophis savignyi* for Palestine (Jaffa) and Syria; *Tarbophis fallax* Fleischmann "may occur in Northern Syria;" *Tarbophis güntheri* Anderson is known from Sinai (South Sinai: El Heswa, Wadi Firan) and Syria (Werner 1898); *Malpolon monspessulanum* Hermann is recorded from Sinai (doubtful: Werner 1893, Hart 1891), Palestine, Transjordan, Syria; *Psammophis schokari* Forsk., Sinai, Palestine (Gaza, Jaffa), Syria; *Macroprotodon cucullatus* Geoffr., South Palestine (Rafa, near Gaza).

Micrelaps mülleri is so far known from Palestine only; the only locality beyond the boundaries of Palestine is Lattakieh (*vide* Lortet in Tristram). Werner does not mention this species as occurring in Syria. We have, therefore, no clear idea about its range; our localities are situated in the Central Hills (Jerusalem), at the south-western end of Lake Tiberias — from this place, also, two specimens with "inverted" colour pattern were found; and in Upper Galilee. The species is unknown from the southern part of the country.

As a new species we may add *Tarbophis nigriceps* Ahl; the type has been described from Iraq¹; our specimens were found in Transjordan, (several kms south of Amman) and in the Negev. This snake differs strikingly in behaviour from *T. savignyi* which rolls up into a ball when roughly handled; *T. nigriceps* is devoid of this instinct. *Tarbophis güntheri* enters the Rift Valley from the South; we have several records: from the Judean desert, from the northwest end of the Dead Sea¹⁷ and from the eastern slopes of the Emek to the Jordan Valley (Mt. Gilboa). Thus there exists a bridge between Flower's locality in Sinai and Werner's (1898) reference of this species for Syria. Strangely enough, Werner omits mention of this species in his later work²².

Boulenger's remark on the occurrence of *T. fallax* in northern Syria (1896, p. 49) has

not been confirmed by Werner. Peracca's and Angel's "*T. vivax*" from Syria are probably *savignyi*, as Werner lists a series of *savignyi* (= *T. fallax syriacus*)-localities from the coastal area (the Lebanon) and the hinterland. The H.U. Collection has no specimens from the Negev (from this area, *nigriceps* only) or Transjordan. Werner refers Boulenger's and Peracca's specimens simply to *savignyi*.

Malpolon monspessulanum cannot be called "a rock and desert snake" (Tristram); I should rather say the contrary, for it avoids deserts and prefers a denser vegetation. This species is well known from the Lebanon, Syria, Palestine and Transjordan (many authors), but, as we saw above, the locality "Sinai" has not been confirmed since Werner's paper in 1898. The specimens of our area belong to the ssp. *insignitus* Geoffroy.

Coelopeltis moilensis Reuss has been reported from Palmyra (Syria) by Angel². Otherwise, this snake is unknown from our area, but is found in Iraq, Arabia and Egypt.

Werner²² thinks that *Psammophis schokari* is a typical desert-snake, and accordingly doubts Jan's locality, Beirut. I am not of Werner's opinion. Angel reconfirms the locality and *schokari* is indeed not exclusively a desert-dweller. It is known from the whole coastal area of Palestine as well as from the hills and desert landscapes. In specimens found in relatively damp localities four dorsal stripes form a striking contrast against the brighter ground colour; in specimens from more arid localities these bands are less conspicuous and show different grades of obliteration — the central part of each stripe may be as bright as the ground colour, while series of small regular dark dots persist at the border of each stripe — or these border-markings may even vanish, leaving the snake plain buff or plain brown. The darkest markings (stripes) are seen in specimens from the coastal plain and from the hill areas, where larger amounts of rainfall and higher main humidity prevail. Barbour (1914) is wrong, too, introducing this species as "a common sand snake". It may be found in the rocky hills and on slopes covered by boulders as well as in the coastal dunes. This snake is known from Sinai, Palestine, Transjordan, Syria (Palmyra and Beirut). In Palestine this euryoecous type may be found everywhere.

Since the appearance of Fower's data on *Macropotodon cucullatus* in southern Palestine (Rafa, Gaza), no other specimens have been brought to our knowledge.

Colubridae proteroglyphae

Naja haje L. "is rare in Palestine"; it is "well known in the plains and downs beyond Beersheba; I met with it near Gaza, on the sandy plain" writes Tristram. Flower, however, admits that he has no knowledge of this species from Palestine or Sinai. Since this reference of Tristram, no specimen has been caught by any local collector and there is no specimen from the east side of the Suez Canal in the British Museum Collection. We obtained two specimens of *Walterinnesia aegyptia* Lataste from Palestine. Perhaps

Tristram's cobras belonged to this species (but *Walterinnesia* is so extremely rare, that even this possibility may be discounted as very improbable). One specimen was found in Bir Asluj (Negev, south of Beersheba) and the second specimen was brought, by an Arab, from the Judean desert (probably from the neighbourhood of Nebi Musa on the Jerusalem-Jericho road) (H.U. Collection). The geographical situation of these localities can be taken as proof that the species should still be found in Sinai, since it was previously recorded from Egypt only. Perhaps this species is linked, by a bridge of dispersal crossing Transjordan in the South, to its nearest relative or even co-specific counterpart from Iraq, *Naja morgani* Mocquard.

Viperidae

Owing to numerous changes in nomenclature and systematic arrangement which have been made since Tristram's time it appears hopeless to determine exactly which species of *Viperidae* this author had in mind.

His list follows :

1. *Vipera euphratica* Martin = *lebetina* L. (fide Boulenger): Galilee; Jericho (Lortet).
2. *Vipera ammodytes* L.: lower slopes of the Lebanon.
3. *Daboia xanthina* Gray = *V. lebetina* L. (fide Boulenger): Plain of Acre, near Tiberias.
4. *Cerastes hasselquistii* Strauch = *Cerastes cerastes* L.: desert country of southern Judea.
5. *Echis arenicola* Boie = *colorata* Günther: "on the dry sands north and west of the Dead Sea".

According to Flower the following *Viperidae* live in our area :

Vipera ammodytes L.: Syria; *Vipera lebetina* L.: Tripoli (Syria) and Palestine; *Pseudocerastes fieldii* Schmidt: from Transjordan (Bair Wells, Um Muwal) and Central Sinai ("White Ridges"); *Cerastes cerastes* L.: Sinai (Abu el Tilûl; Wadi Hareidhin); (Werner 1893, Anderson 1904, Andres 1920); Palestine; Transjordan (Boulenger 1896), (Anderson 1898; Barbour 1914).

Cerastes vipera L.: Sinai (Katia; East of Lake Timash; Mahadat; Habel el Maskar; Gebel Masheiti, Tor); southern Palestine (near Gaza).

Echis carinata Schn.: northern Syria, not from Sinai or southern Palestine.

Echis colorata Günther: Sinai (Wadi Firan [Anderson 1904]); Palestine (Jordan Valley); Transjordan (Kerak, Aqaba [Barbour 1914]).

Concerning the genus *Vipera* I agree with Werner²¹ rather than with Schwarz¹⁷: Werner mentions three vipers for Syria — Lebanon, viz.: the "Mountain Viper" *V. xanthina* Gray (= *bornmuelleri* Werner), from the Lebanon (2,000 m.); ac-

cording to Werner²² there is no doubt that this species is identical with Tristram's *V. ammodytes* (from the Lebanon). Schwarz¹⁷, however, mentions *Vipera ammodytes meridionalis* Blgr. (from the British Museum Collection) as occurring in the Lebanon*; as scattered localities from Anatolia are known (Cilicia Konia, Bosphorus), this seems to be the last outpost of the species); a second species, *V. palaestina* Werner, is known mainly from Palestine and from Syria (Jebelie, south of Latakia). The third, *V. lebetina* L., is known from Syria (Aleppo) and the Lebanon (Beirut) as well as from northern Palestine (Acre). The H.U. Collection has specimens of *V. palaestina* from the coastal plain (near Tel Aviv), the Emek, as well as from the Central Hills (near Jerusalem). We are still ignorant of the exact boundaries between *palaestina* and *lebetina* in Israel and have no knowledge of their occurrence in Transjordan. Schwarz's *Vipera lebetina lebetina* and *lebetina xanthina*, are, according to Werner, not correctly defined. As insufficient material is at my disposal now, I can only stress the very unsettled state of this group; *lebetina* is probably restricted to the extreme North only (Werner²¹).

Pseudocerastes fieldii: the H.U. Collection has specimens from Transjordan (W. Dhoba'i) and southern Palestine (Negev); the gap between Sinai and Transjordan is, therefore, closed. In the meantime, this species has been found in Central Arabia also (manuscript).

Cerastes cerastes is probably limited to the South of Palestine and the southern part of the Jordan depression (Transjordan : East of the Dead Sea : Kerak (Barbour); Araba [Strauch]). We have a specimen from Asluj in the Negev; we have also a specimen of *C. vipera* from the same place.

Echis colorata is not rare in the southern wadis of the Judean desert; we have specimens from the area Jericho — Wadi Kelt — Kallia — Ain Feshkha, and one from the north-eastern slopes of Mount Gilboa, rather far in the North.

From the western border of the Dead Sea (Ein Geddi), my colleague, Dr. Mendelsohn, brought a specimen of a genus so far unknown from the whole area, representing a new species, *Atractaspis engaddensis* Haas¹⁰. This genus has a wide distribution in tropical Africa and tropical parts of Arabia; perhaps the locality nearest to our own is the Sudan. This completely isolated occurrence of a tropical snake in Palestine is of the highest interest. The local conditions of extreme heat combined with relative abundance of water may have favoured the survival of this form.

* See Addendum No. 7.

ADDENDA

As I had the opportunity to work at the British Museum of Natural History I could revise and complete some of the statements made in this paper. On this occasion I wish to express my thanks to Dr. H.W. Parker and Mr. J.C. Battersby, who both gave me very useful help and advice.

The Addenda bear numbers according to those in the text of this paper.

1. *Trionyx euphratica*. Siebenrock (1913) has no knowledge about the occurrence of *T. triunguis* in the coastal area of Palestine and even dismisses the possibility of its occurrence in Beirut (Strauch 1890). The specimen in the Vienna Museum from the Lake of Tiberias seems to Siebenrock of doubtful origin, because he thinks that *euphratica* should live at this locality, if *Trionyx* lives there at all. But, according to him, this specimen is a real *triunguis*. He is doubtful about the correctness of the locality and thinks that Strauch's specimen from Beirut could have been brought from Egypt!

2. *Bunopus tuberculatus*. The specimen at hand (♀) shows a mixture of *B. tuberculatus* as well as *blanfordii* characters. The continuation of the preanal series of scales on the ventral side of the femur is not clearly set off from the more caudal, smaller series; the head, however, in having rather the slender proportions of *blanfordii*, has the slightly concave contour — seen from en face — in the frontal region as in *tuberculatus*. The strongly protruding trihedral scales of the back point also more in the direction of *tuberculatus*.

3. As there is only one *Agama* in the sandy stretches of Southern Palestine, whose nomination seems to be rather instable, it seems better to name the species not as Flower did, but in accordance with the specimens in the British Museum (N.H.), namely *A. flavimaculata* Rüppell = *leucostigma* Reuss. (After Flower = *flavimaculata* Anderson 98 and not Rüppell).

4. *Ablepharus festae* Peracca (= *A. brandtii festae* Schmidt 1939). In the British Museum (N.H.) Collection there is one of the Types of *A. brandtii* (from Es Salt); this proved to be a simple *A. kitaibelii*. We have, therefore, to cancel this species.

5. New observations point more to the view that Boulenger's rather complex var. *olivieri* should be given full specific rank; the *olivieri* specimens from Sinai and Palestine differ in several characters (Haas, Manuscript) from the other *olivieri* forms and should, therefore, be kept apart as a subsp. *schmidtii*. (4 enlarged tibial scales ventrally; as a rule 5 supralabials in front of subocular; strongly keeled ventral scales of the yellow tail).

6. *Contia collaris* Ménétr. Dr. Parker splits Boulenger's species (with 15 and 17 scalerows, respectively), naming provisionally (personal information) the specimens with the higher scale numbers *collaris modesta*, the other *collaris collaris*. Under the first group one specimen (1920.1.20.1507) from the Lataste Collection bears the locality

Dead Sea. The locality is, however, of doubtful validity, as I have been informed. In the same collection are several specimens of this type from the Lebanon region! (10).

Contia collaris modesta reaches a considerable size (Dead Sea specimen: ca. 560 mm.), whereas *C. rothii* are probably always considerably smaller (1 specimen of exceptional size at hand: 330 mm.), Schmidt's *collaris* (1939) has, however, 15 scales across the body, is therefore a *C. collaris collaris*.

7. *Vipera ammodytes*. In the British Museum (N.H.). Collection there is one specimen (Tristram Collection, 1905.6.27.4.) labelled Lebanon. This specimen is of doubtful origin, as the locality *Syra* has been changed into *Lebanon* — probably in misreading *Syra* for *Syria*; further details concerning the origin of this specimen were not available as in the Inventory Catalogue the place *Syra* only is given. Perhaps Tristram took the small *Vipera xanthina* for *V. ammodytes* (see also Müller-Wettstein 1933).

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APPENDIX

- List of the Reptiles known from Israel (I.) and Jordan (J.) (Both sides of Jordan).
1. *Crocodylus niloticus* Laurenti I. (extinct).
 2. *Testudo graeca ibera* Pallas I. J.
 3. *Testudo graeca floweri* Bdh. I. J. ? (of dubious validity).
 4. *Clemmys caspica rivulata* (Valenciennes) J. I.
 5. *Trionyx triunguis* (Forsk.) I.
 6. *Caretta caretta* (L.) I.
 7. *Chelonia mydas* (L.) I. J.
 8. *Eretmochelys imbricata* (L.) I. J.
 9. *Stenodactylus sthenodactylus* (Licht.) I. J.
 10. *Stenodactylus grandiceps* Haas I.
 11. *Tropicolotes steudneri* (Peters) I. J.
 12. *Tropicolotes nattereri* Steindachner I., probably J. (of doubtful validity).
 13. *Ceramodactylus doriae* Blanford I.
 14. *Bunopus tuberculatus* Blanford I.
 15. *Pristiurus flavipunctatus guweirensis* Haas J.
 16. *Gymnodactylus kotschyi orientalis* Stepanek I.; probably J.
 17. *Hemidactylus turcica* (L.) I. J.
 18. *Ptyodactylus hasselquistii* (Donndorf) I. J.
 19. *Ptylodactylus hasselquistii puisieuasi* Boutan I. J.
 20. *Agama pallida* Reuss I. J.
 21. *Agama persica* Blanford J.
 22. *Agama sinaita* Heyden I. J.
 23. *Agama flavimaculata* Rüppell I.
 24. *Agama stellio* (L.) I. J.
 25. *Agama stellio picea* Parker J.
 26. *Uromastix aegyptia* (Forsk.) I. J. (most probably).
 27. *Chamaeleon chamaeleon* L. I. J.
 28. *Ablepharus kitaibelii* Bibron et Bory I.
 29. *Ablepharus brandtii festae* Peracca. J. = 28^a
 30. *Mabuya vittatus* (Olivier) I. J.
 31. *Eumeces schneideri syriacus* Böttger I. J.
 32. *Ophiomorus latastii* Günther I. J.
 33. *Chalcides ocellata* (Forsk.) I. J.
 34. *Chalcides sepsoides* (Audouin) I.
 35. *Chalcides guentheri* Boulenger I.
 36. *Scincus stincus* (L.) I.
 37. *Scincus spec.* J.
 38. *Lacerta viridis strigata* Eichw. I.
 39. *Lacerta laevis* Gray I. J.
 40. *Acanthodactylus schreiberi syriacus* Böttger I.
 41. *Acanthodactylus scutellatus* (Audouin) I.
 42. *Acanthodactylus grandis* Boulenger J.
 43. *Acanthodactylus robustus* Werner J.
 44. *Acanthodactylus tristrami* Boulenger J.
 45. *Acanthodactylus pardalis* (Lichtenstein) I.
 46. *Acanthodactylus boskianus asper* Boulenger I. J.
 47. *Eremias guttulata* (Lichtenstein) I. J.
 48. *Eremias olivieri schmidtii* Haas I. J.
 49. *Eremias brevirostris* Blanford J.
 50. *Ophisops elegans Ménétries* J.
 51. *Ophisops elegans ehrenbergii* Wiegmann I. J.
 52. *Ophisops elegans schlueteri* Böttger I. J.
 53. *Ophisops elegans mizolepis* Stolicka I. J.
 54. *Ophisaurus apodus* (Pallas) I. J.
 55. *Varanus griseus* (Daudin) I. J. (very improbable: *Blanus strauchii* Bedriaga. I.)
 56. *Typhlops vermicularis* Merrem, I.
 57. *Typhlops simoni* Böttger I. J.
 58. *Leptotyphlops macrorhynchus* Jan I. J.
 59. *Eryx jaculus* (L.) I. J.
 60. *Natrix tessellatus* (Laurenti) I. J.
 61. *Coluber jugularis jugularis* (L.) I. J.
 62. *Coluber najadum* Eichwald I. J.
 63. *Coluber rhodorhachis* (Jan) I. J. (probably).
 64. *Coluber rogersi* (Anderson) I. J.
 65. *Coluber elegantissimus* (Günther) (J. most probably).
 66. *Coluber nummifer* Reuss I. J.
 67. *Spalerosophis diadema* (Schlegel) I. J. *Spalerosophis* another subspecies (?) J.
 68. *Lytrochynchus diadema* (Dum. et Bibr.) I. J. probably, but in this case the Arabian sp.
 69. *Oligodon melanocephalus* (Jan) I. J.
 70. *Eirenis decemlineata* (Dumeril et Bibron) I. J.
 71. *Eirenis collaris* (Ménétries) (I. ?) J.
 72. *Eirenis rothi* Jan I. J.
 73. *Eirenis coronella* Schlegel I. J.
 74. *Eirenis coronella fraseri* Schmidt (J. ?).
 75. *Eirenis lineomaculata* Schmidt I. J.
 76. *Micrelaps muelleri* Böttger.
 77. *Tarabophis savignyi* Boulenger I. J.
 78. *Tarabophis guentheri* Anderson I. J.
 79. *Tarabophis nigriceps* Ahl I. J.
 80. *Malpolon monspessulanus insignitus* Geoffroy I. J.
 81. *Psammophis schokari* (Forsk.) I. J.
 82. *Macroprotodon cucullatus* (Geoffroy) I.
 83. *Walterinnesia aegyptia latastei* I. J.
 84. *Vipera lebetina* L. I. (?)
 85. *Vipera palaestina* Werner I. J.
 86. *Pseudocerastes fieldii* Schmidt I. J.
 87. *Cerastes cerastes* (L.) I.
 88. *Cerastes vipera* (L.) I.
 89. *Echis colorata* Günther I. J.
 90. *Atractaspis engaddensis* Haas I. (J. probably).

*See Addendum No. 4

A NOTE ON EAST MEDITERRANIAN SPECIES OF THE GENUS HAEMAPHYSALIS ⁽¹⁾*

B. FELDMAN-MUHSAM

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The descriptions of species within the genus Haemaphysalis are often incomplete and insufficient for specific diagnosis particularly in the case of Mediterranean species. This has resulted in considerable confusion and specific determination on the basis of extant literature is difficult. In this paper it is shown that by application of the characters used in the case of the genus Hyalomma it is possible to clear up this confusion and provide data for accurate specific diagnosis. This is essential in view of the fact that the genus Haemaphysalis contains proved carriers of rickettsiae and Babesia canis.

The following species of the genus *Haemaphysalis* have been recorded from the near East:

Haemaphysalis cinnabarina var. *punctata* (Canestrini, and Fanzago, 1877). Nuttall et al., 1915, from Egypt, Asia Minor, Macedonia and Crete;

H. spinigera Neuman, 1897 from "Judea";

H. leachi (Audouin, 1827) Neuman, 1897, from Egypt;

H. cornigera Neuman, 1897, from "Judea";

H. calcarata Neuman, 1902, from Egyptian Soudan;

H. punctata var. *cretica* Senevet and Caminopetros, 1936, from Crete;

H. otophila Schulze, 1918, from Macedonia.

Unfortunately the original descriptions of all the above mentioned species are vague and not based on decisive characters so that diagnosis is difficult and uncertain. It is probable that *H. punctata* var. *cretica* Senevet and Caminopetros, 1936¹, is a synonym of *H. nicolleti* Laroche, 1925². On the other hand the ticks included by Nuttall and Warburton³ in *H. cinnabarina punctata* contain in our opinion, three distinct species of which two *H. otophila* Schulze, 1918⁴, and *H. punctata* var. *cretica* have been collected in this country on different hosts. An examination of material in our collection

(¹) This work was carried out under the auspices of, and with a grant from the Research Council of Israel.

* Received April 1951

has convinced us that the methods established for identification of species of the genus *Hyalomma* by Adler and Feldman-Muhsam^{5, 6} are useful for specific determination in the genus *Haemaphysalis* and are probably valid for other genera of the *Ixodidae* e.g. *Amblyomma* and *Dermacentor*⁷. Ambiguities in specific nomenclature in the genus *Haemaphysalis* can only be eventually cleared up by examining type material for constant characters particularly the genital aperture of the female. In the meantime we are compelled to use the incomplete taxonomic data available. In the present paper we present new data for the taxonomy of *H. punctata*, *H. cretica* and *H. otophila*, and add two new species: *H. adleri* and *H. erinacei*.

HAEMAPHYSALIS CRETICA (Senevet and Caminopetros, 1936) n. comb.

Synonymy:

H. cinnabarina var. *cretica* Senevet and Caminopetros, 1936,

H. punctata var. *cretica* Senevet and Caminopetros, 1936,

? *H. nicolleti* Larrouse, 1925.

Haemaphysalis cretica was described as a variety of either *H. punctata* or *H. cinnabarina* by Senevet and Caminopetros and in our opinion should be raised to specific status on the basis of distinctive taxonomic characters.

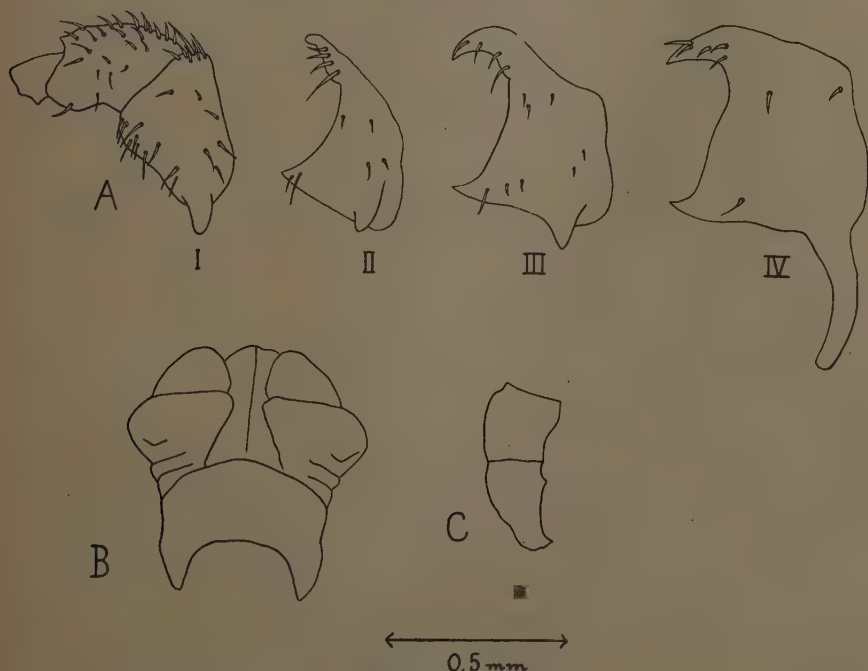


Fig. 1 *H. cretica* male: A — Coxae, B — Capitulum, C — Tarsus leg IV.

Male.

The male is characterized by an elongated scutum covered uniformly with small punctations. Its length from the middle of the line joining the tips of scapulae to the posterior margin is about 3.5 mm. The lateral grooves are sharply defined, very long and begin at the level between coxae II and III. The basis capituli is rectangular with long cornua. There is a strong ventral retrograde spur on article 3 of the palp. First coxa with a short spur. Coxa II and III with a short spur (sometimes very short). Coxa IV with a very long spur almost as long as the coxa, and always directed laterally (Fig. 1, A, IV). The trochanters, especially those of the first pair, are very pilose (Fig. 1, A, I.) The dentition of the hypostome is 5/5 or 6/6. The denticles become progressively larger from the distal to the proximal row.

Female.

The scutum is longer than broad and is covered uniformly with small punctations. Its length from the middle of the line joining the tips of the scapulae to the posterior margin is about 1.4 mm. The gorged female attains about 14 mm. in length. The basis

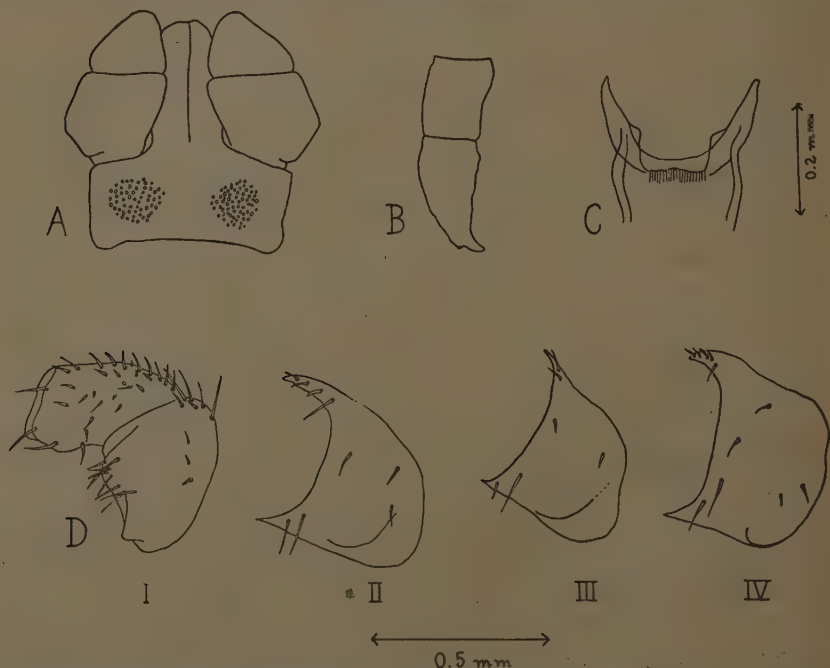


Fig. 2 *H. cretica* female: A — Capitulum, B — tarsus leg IV, C — Genital aperture, D — Coxae.

capitulum is rectangular. There are no cornua. There is a strong ventral retrograde spur on article III of the palps as in the male. Coxa I has a very short spur, Coxae II, III, and IV have only a bulge in place of a spur (Fig. 2,D). Occasionally the bulge on coxa IV is somewhat enlarged and directed laterally along the lower aspect of the coxa. The trochanters, especially of the first pair of legs are very pilose as in the male (Fig. 2,D,I). The dentition of the hypostome is 4/4 sometimes 5/5.

The sexual aperture of the female (Fig. 2,C) is characteristic and may be distinguished from other local species. The distance between the two lateral chitinous flaps is constantly relatively larger than in *H. otophila*. This species differs from *H. punctata* in the following details: the males of *H. cretica* seem to be somewhat larger (3.3-3.7 mm), the spur on the fourth coxa is directed laterally, the trochanters are pilose. The cornua on the basis capituli are long. The length of the males of *H. punctata* ranges from 2.4-3.3 mm; the spur on the fourth coxa is directed medially, and the cornua are shorter than in *H. cretica*. The female of *H. cretica* differs from that of *H. punctata* in the pilose trochanters, longer and stouter legs, and in the absence of spurs on coxae II and III (all the coxae of *H. punctata* bear well marked spurs).

H. cretica is apparently rare in Palestine. From a large collection of many thousands of ticks collected during two years (1928-29), made by the mandatory government of Palestine, only 240 specimens were found. The ticks were practically from all parts of the country. The hosts were goat, sheep, camel, and cow. The adult ticks are found on the hosts during the winter months (November-February) only.

Among *H. cretica* of our collection, 66% were taken from goat, 23% from sheep and the remaining 9% from cattle and camels. In view of the fact that more *Haemaphysalis* ticks had been collected from goat than from sheep, the above percentages may present an exaggerated picture of the actual preference of *H. cretica* for the goat. As a matter of fact, 46% of all *Haemaphysalis* ticks taken from goat were *H. cretica* while among *Haemaphysalis* ticks taken from sheep 26% proved to belong to this species. The difference between these percentages has been shown by χ^2 test to be highly significant statistically.

HAEMAPHYSALIS OTOPHILA Schulze, 1918.

Syn.: *H. cinnabarina* var. *punctata* (Canestrini and Fanzago, 1877) Nuttall *et al.*, 1915, p.p.

This species was created by Schulze for specimens which he found in Macedonia on several hosts (cattle, sheep, goat, donkey and dog).

Nuttall described similar specimen from Transcaucasia and considered them as atypical forms of "*H. cinnabarina punctata*".

Schulze's description is not complete, but the characters of the capitulum and coxae as figured by him resemble those found in our material and differ from "*H. cinnabarina*

punctata" especially by the absence of a long spine on the IV coxa of the male. The palps are less salient laterally than in *H. punctata*. The female differs from *H. punctata* in the short cornua which are absent in *H. punctata*.

Male.

Specimens are smaller than those of *H. cretica*. The length of the scutum of the male is about 2.3-2.6 mm. The colour of the scutum is red brown. It is uniformly covered with small punctations. The lateral grooves are long narrow and sharply defined. They begin at the level between coxae II and III. The basis capitulum is rectangular

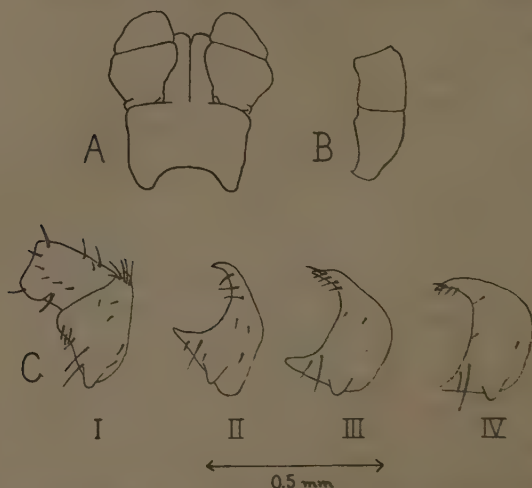


Fig. 3 *H. otophila* male: A — Capitulum, B — Tarsus leg IV, C — Coxae.

and has short cornua (Fig. 3,A). There is a retrograde spur on the ventral side of article 3 of the palp. The spurs on all coxae are small and about the same size. The hairs on the trochanters are scanty (Fig. 3,C,I). The dentition of the hypostome is 4/4, with an additional incomplete row (sometimes also 5/5). Corona distinct.

Female.

The female is much nearer to *H. punctata* than the male. The scutum is about 1.1-1.2 mm. in length, is longer than broad, its colour is reddish brown, and it is uniformly covered with small punctations. The basis capitulum is rectangular, with very short cornua. The second article of the palp is slightly notched on its lateral margin. The notch is situated above a small lateral projection (Fig. 4,A, compare with palpes of *H. cretica*). Article 3 bears ventrally a retrograde spur. All coxae bear short but well

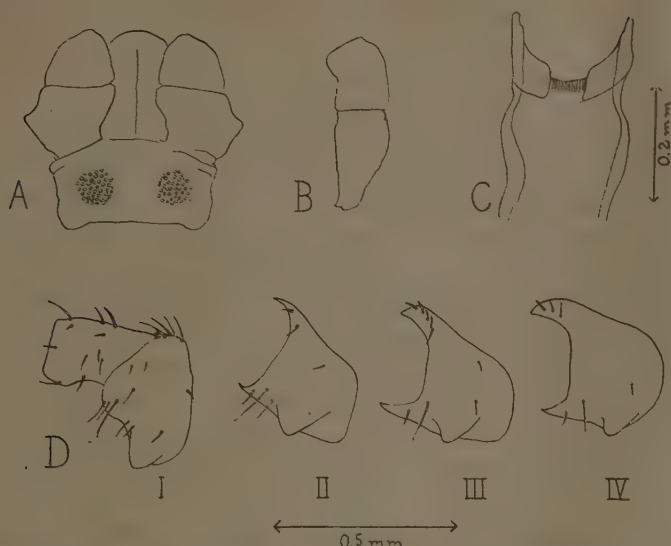


Fig. 4 *H. otophila* female: A — Capitulum, B — Tarsus leg IV, C — Genital aperture, D — Coxae.

marked spurs. The hairs on the trochanters are scanty, as in the male. The dentition of the hypostome is 4/4. The genital aperture is specifically characteristic (Fig. 4,C). The distance between the median corners of the two lateral flaps is shorter than in *H. cretica*. The gorged female is smaller than that of *H. cretica* and does not attain more than 10 mm. This species is much more abundant in this country than *H. cretica* and was found on a greater variety of hosts viz. sheep, goat, camel, dog, cattle, mule, horse. Thirty eight per cent of the specimens in our collection were found on sheep and 33% on goats, 14% on cattle and the remaining 15% on various other animals. Taking into consideration as mentioned above that more *Haemaphysalis* ticks had been taken from goat than from sheep the above percentages do not reflect the actual preference of *H. otophila* for sheep. As a matter of fact, 74% of all *Haemaphysalis* found on sheep were *H. otophila* while 54% of those found on goat belong to this species. This difference between these percentages has been shown as mentioned above, to be highly significant statistically. The ticks are not found only in the ears as Schulze thought, but they can also be met with in the tail, under the belly, thighs, abdomen, udder and jaw. The ticks were found all over the country during the winter months October-February.

The distinct characters which readily distinguish between the females of *H. otophila* and *H. cretica* are: hairy trochanters, absence of the lateral projection on article two of the palp, small bulges on coxae II, III, IV, and the form of the genital aperture in *H. cretica*. In *H. otophila* the hairs on the trochanters are scanty; there is a small notch

above the lateral projection on the second article of the palp, and there are short spurs on all coxae.

HAEMAPHYSLAIS PUNCTATA Canestrini and Fanzago, 1877.

Syns.: *H. punctata punctata* (Canestrini and Fanzago, 1877) Neuman, 1911,

H. cinnabarina var. *punctata* (Canestrini and Fanzago, 1877) Nuttall *et al.*, 1915, p.p.

Neumann⁸ divided this species into 2 varieties, *H. punctata punctata* and *H. punctata cinnabarina*. Nuttall gives priority to Koch's type *cinnabarina* and reduces *H. punctata* to the status of a variety of *H. cinnabarina*, which is a South American species. Nuttall further considered *H. chordeilis* (recorded from U.S.A. and Canada) to be a synonym of *H. cinnabarina*. Cooley⁹ on the other hand retains the name *H. chordeilis* for North American specimens. Nuttall based his opinion on the re-examination of Koch's unique type of *H. cinnabarina*. We have had no opportunity of examining South American specimens but through the kindness of Dr. G.M. Kohls of the Rocky Mountain Laboratory we obtained specimens of *H. chordeilis* determined by him. A study of these specimens leaves no doubt that *H. punctata* is quite distinct from *H. chordeilis* both on gross characters and structure of the genital aperture of the female. These findings indicate that *H. punctata* is a distinct species and not a variety of *H. cinnabarina* or *H. chordeilis*.

H. punctata has not been found in the material so far collected in Palestine, but in view of the fact that Nuttall's descriptions of *H. punctata* is incomplete with regard to essential taxonomic characters and relates to at least three species, we think it useful to

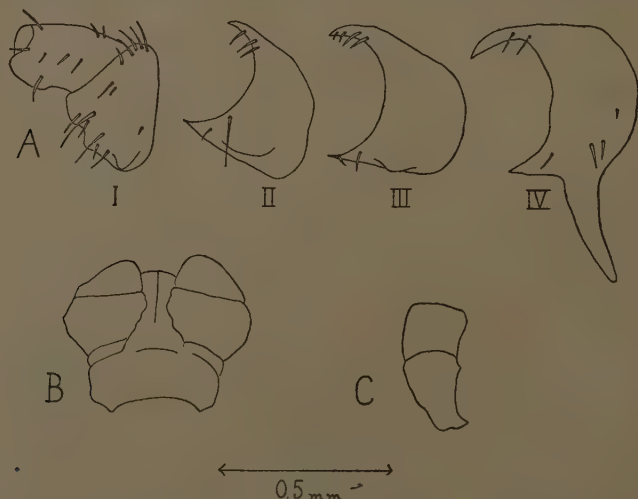


Fig. 5 *H. punctata* male: A — Coxae, B — Capitulum, C — Tarsus leg IV.

give a complete description on the basis of material kindly furnished by Prof. Ed. Sergeant, the director of the Institut Pasteur of Algeria.

Male.

Scutum, oval, reddish brown in colour and about 2.3 mm in length; uniformly covered with small punctations. The lateral grooves are narrow and begin at the level between coxae II and III. The basis capituli is rectangular, with short cornua (Fig. 5, B). There is a short retrograde spur on the ventral side of article 3 of the palp. Coxae I, II and III bear short spurs, coxae IV bears a long spur, always directed medially (Fig. 5, A, IV). The hairs on the trochanters are as scanty as in *H. otophila* (Fig. 5, A, I). The dentition of the hypostome is 5/5, 8-9 teeth per file.

Female.

The scutum is longer than broad, and about 1.2 mm in length. The lateral margins of the scutum do not form a smooth curve posteriorly but as Nuttall remarks "is broken by slight posterolateral angles". The basis capituli is rectangular, with no cornua (Fig. 6, A). The areae porosae are very large and occupy almost the entire basis capituli. Article 3 of the palp bears ventrally a short retrograde spur. All coxae bear short but well marked spurs. The spur on coxa IV is sometimes somewhat longer than on II and III. The hairs on the trochanters are scanty as in the male. The dentition of the hypostome is 5/5 (sometimes there is an additional incomplete row) 11-13 teeth per file. The genital aperture is specifically characteristic (Fig. 6, C). The lateral flaps are thin.

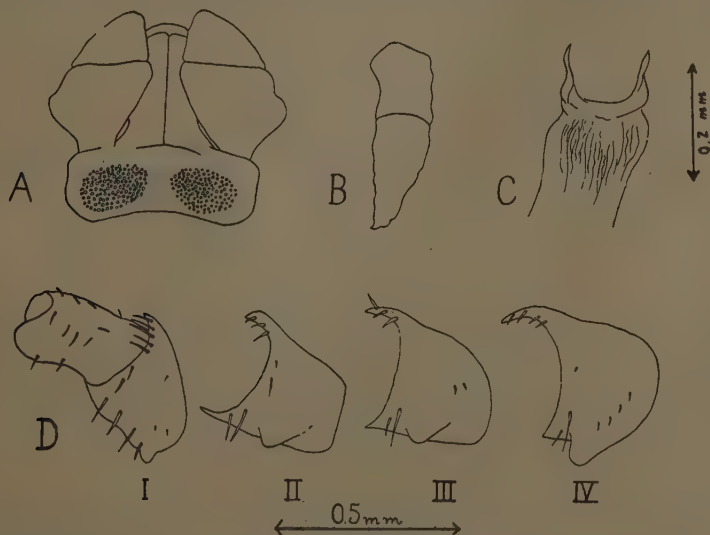


Fig. 6 *H. punctata* female: A — Capitulum, B — Tarsus leg IV, C — Genital aperture, D — Coxae.

HAEMAPHYSALIS ADLERI n. sp.

This species resembles *H. leachi* in some respects, especially in the form of the capitulum, but differs in some essential features and should therefore be considered as a new species.

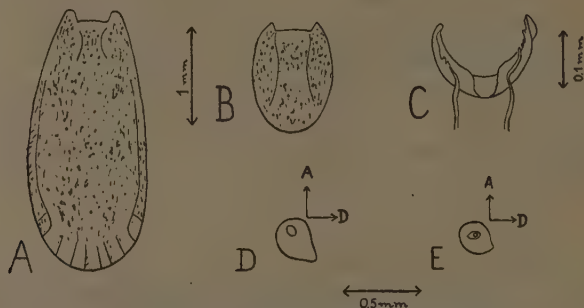


Fig. 7 *H. adleri*: A—Male scutum, B—Female scutum, C—Female genital aperture, D—Male spiracular plate, E—Female spiracular plate.

Male.

It is a small tick. The length of the scutum is about 2.2 mm. The scutum is long oval, with many large punctations. Lateral grooves are long and distinct, they begin at the level between coxae II and III and include 2 festoons. The median festoons are twice as long as broad. The whole scutum is covered with numerous long hairs (Fig. 7, A). The palps meet anteriorly at a very obtuse angle. Article two of the palp is very salient laterally and with retrograde projections, 2 dorsal, and 1 ventral (Fig. 8 A and B). The

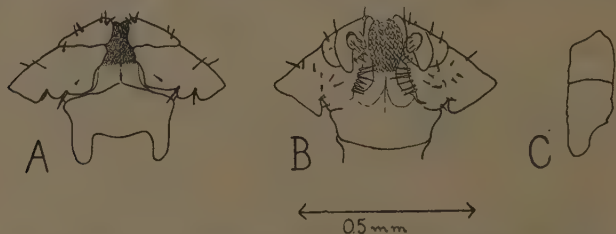


Fig. 8 *H. adleri* male. A—Capitulum dorsum, B—Capitulum venter, C—Tarsus leg IV.

basis capituli is broadest in front. The cornua are strong and long. Article 3 of the palp bears ventrally a retrograde process. The dentition of the hypostome is 4/4, 7 teeth per file. All coxae have small spurs on their medial aspect.

Female.

The scutum is elongated, oval in shape with numerous large punctations. It is covered with long hairs as in the male (Fig. 7, B). Its length is about 0.9 mm. The palps

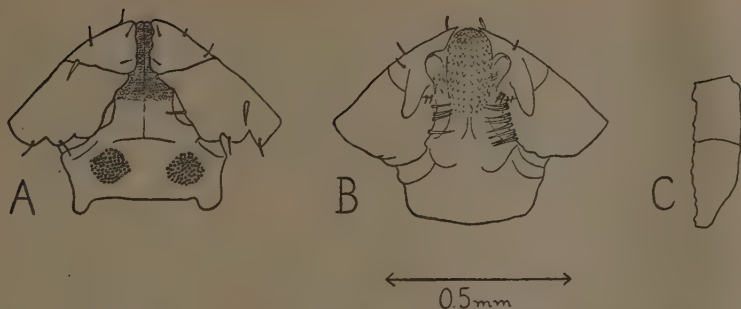


Fig. 9 *H. adleri* female: A — Capitulum dorsum, B — Capitulum venter, C — Tarsus leg IV.

resemble those of the male but meet at a less obtuse angle. The basis capituli is rectangular, cornua, well shaped, porose areas round and far apart (Fig. 9, A). The dentition of the hypostome is 4/4, 8 teeth per file. Ventrally there are no retrograde process in article 2 of the palp. Coxa I bears a strong spur, the other coxae small spurs. The genital aperture is hemispherical, parts of the inner margins of the lateral flaps are serrated, and the distance between the basis of the flaps is relatively short (Fig. 7, C).

H. adleri was found twice on jackal by Dr. I. Saturen: 3 males on 21/11/50 and 1 male and 1 female on 22/12/50 both times in Ness-Ziona. We dedicate this species to Prof. S. Adler.

HAEMAPHYSALIS ERINACEI. n. sp.

This species also resembles *H. leachi*, but differs in some important characters and should be separated as a new species.

Male.

The colour of the whole tick is tannish yellow. The scutum is oval and covered with large and scattered punctations. It's length is about 2 mm. The lateral grooves are

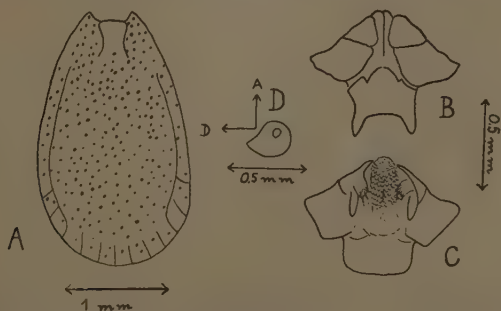


Fig. 10 *H. erinacei* male: A — Scutum, B — Capitulum dorsum C — capitulum venter D — Male spiracular plate.

long and begin at the level between coxae II and III. The palps meet anteriorly at an obtuse angle. Article two of the palp is very salient laterally and has no retrograde projections as in *H. leachi* and *H. adleri* (Fig. 10 B and C). The basis capituli is broadest in front. The cornua are long and strong. There is a strong ventral retrograde process on article 3 of the palp. The dentition of the hypostome is 4/4, 7 teeth per file. All coxae bear small spurs.

Female unknown.

Described from 1 specimen collected on hedgehog in Jerusalem on 22/7/49 by Dr. Mendelson.

The following are the keys to the species described in the present paper :

Key to Females

- 1) Article II of the palps very salient laterally; palps converge anteriorly and form a very obtuse angle; scutum covered with numerous long hairs . . . *H. adleri*
Palps only moderately salient laterally 2
- 2) Trochanters, especially of the first pair, very pilose; coxae II and III with bulges instead of spurs. *H. cretica*
Trochanters only scantily pilose; short spurs on coxae II, III, and IV . . . 3
- 3) No cornua on the basis capituli *H. punctata*
Small cornua on the basis capituli *H. otophila*

Key to Males

- 1) Article II of the palps very salient laterally 2
Article II of the palps only slightly salient laterally 3
- 2) Scutum with many long hairs *H. adleri*
Scutum without hairs; colour tanish *H. erinacei*
- 3) Coxa IV with a long spur almost as long as the coxa 4
Coxa IV with a short spur *H. otophila*
- 4) The spur on coxa IV is directed laterally; the first trochanter is very pilose . . .
. *H. cretica*
The spur on coxa IV is directed medially; the first trochanter is scantily pilose . .
. *H. punctata*

SUMMARY

The local species of the genus *Haemaphysalis* are described. *H. otophila* and *H. cretica* were found on domestic stock.

H. cretica is raised to specific status.

Two new species: *H. adleri* from the jackal and *H. erinacei* from the hedgehog are described.

A description of *H. punctata* on material from Algeria is added for comparison.

I have to thank Prof. Ed. Sergent and Dr. G.M. Kohls for the gift of material and Prof. S. Adler for advice and criticism.

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LETTERS TO THE EDITOR

The editorial Board does not accept responsibility for the views expressed in the letters printed below.

AN ELECTRICAL NETWORK FOR DETERMINING THE ROOTS OF A POLYNOMIAL*

In this paper a simple electrical network for solving polynomial equations is described. As a first step, a network capable of determining the real roots of a third-order real polynomial was constructed. The results obtained were satisfactory, indicating that the same principle can be applied to higher orders. Moreover, it is possible to extend the network so that the complex roots of any polynomial with given maximum degree (including polynomials with complex coefficients) could be determined.

Mathematical Discussion.—

1. A polynomial can be written in a form so that no term contains a power of the variable x greater than unity. For example:

$$a_3x^3 + a_2x^2 + a_1x + a_0 = 0 \quad (1)$$

can be written as:

$$x[a_3x + a_2] + a_1 + a_0 = 0 \quad (2)$$

2. By a suitable substitution of the variable x it is easy to ascertain that all the roots are smaller in their absolute value than $\frac{1}{2}$.

3. The network need only be capable of determining the positive roots; to determine a negative root x_1 we substitute $x_1 = -y_1$ and the polynomial then obtained will have a positive root y_1 .

The Electric Network.

Potentiometers and resistors can be employed to perform multiplication and addition. In Fig. 1:

$$e = E \cdot a \cdot x \quad (3)$$

(where a is the potentiometric ratio of potentiometer R_1 and x — the corresponding ratio in R_2) provided that $R_2 \gg R_1$.

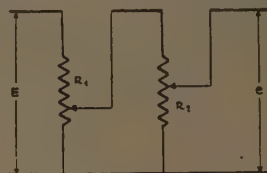


Fig. 1

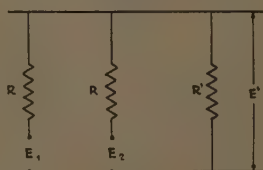


Fig. 2

In Fig. 2:

$$E' = \frac{1}{2}(E_1 + E_2) \quad (4)$$

provided that $R' \gg R$.

These conditions can be achieved in practice by using cathode-follower triodes, as the input impedance of these elements is very high. Referring to Figs. 3 and 4 it is seen that

$$e = E \cdot a \cdot x \cdot g \quad (3')$$

$$E' = \frac{1}{2}(E_1 + E_2) \cdot g \quad (4')$$

where g is the gain of the cathode-followers. In our circuits $g = 0.95$.

* Received March 1951

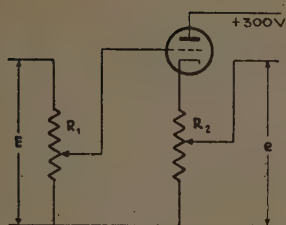


Fig. 3

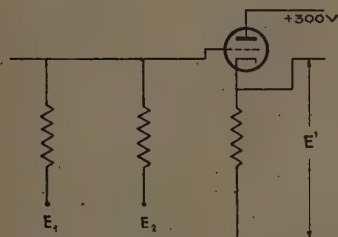


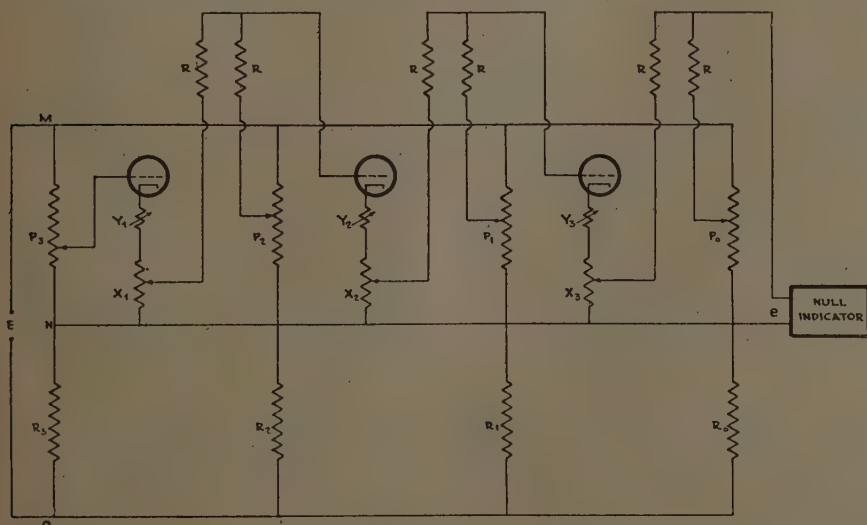
Fig. 4

Using these circuit elements, we obtain the network described in Fig. 5, realizing a third-order polynomial. The network

is excited by an alternating voltage source E . The potentiometers P_3, P_2, P_1, P_0 are equal, and equal to the fixed resistors R_3, R_2, R_1, R_0 . Thus from considerations of symmetry, the voltage between M and N is equal and opposite to that between O and N . P_2, P_1, P_0 are adjusted so that their ratios are equal to a_2, a_1, a_0 respectively, while the ratio of P_3 is made equal to $\frac{1}{2}a_3$. If a coefficient, say a_1 , is negative, the corresponding potentiometer in the network $-P_1$ is interchanged with its corresponding resistor R_1 . The potentiometers X_1, X_2, X_3 are equal and ganged, and their common ratio determines the variable x . Y_1, Y_2, Y_3 are equal rheostats, by means of which the gains of the triodes are adjusted to be equal. As R is large compared to the P and X potentiometers, it follows that the output voltage of the network $-e$ is given by:

$$e = \frac{1}{2}E \left\{ \left[a_3 \left(\frac{gx}{2} + a_2 \right) \frac{gx}{2} + a_1 \right] \frac{gx}{2} + a_0 \right\}$$

$$= \frac{1}{2}E \left[a_3 \left(\frac{1}{2}gx \right)^3 + a_2 \left(\frac{1}{2}gx \right)^2 + a_1 \left(\frac{1}{2}gx \right) + a_0 \right]$$



TUBES : 6 J 6

$P_3 = P_2 = P_1 = P_0 = R_3 = R_2 = R_1 = R_0 = 10,000 \Omega$

$X_1 = X_2 = X_3 = 10,000 \Omega$

$Y_1 = Y_2 = Y_3 = 500 \Omega$

Fig. 5

The ganged potentiometers X_1, X_2, X_3 are varied simultaneously, and the common potentiometric ratios x_1 , for which zero signal is observed in the null-indicator, are determined. The required roots are then given by $\frac{1}{2}gx_1$. In this way all the positive roots are measured; the negative roots are determined by using the above mentioned substitution.

Accuracy.—

The following main factors determine the accuracy of the results:

1. The accuracy with which the potentiometers are adjusted and measured.
2. The accuracy with which the cathode-followers are adjusted to have the same gain g .

The second factor was found to be the limiting factor in the network constructed, introducing an error of 1%. A more careful design will probably reduce this error. Several equations were solved with the aid of the network, and the accuracy of the measured roots was found to be about one percent.

The network can be extended to handle complex roots of polynomials with complex coefficients, by introducing condensers as well as resistors. A complex number will then be realized in the network by an impedance comprising a resistor and a condenser.

The author wishes to acknowledge his indebtedness to the Department of Electrical Engineering of the Massachusetts Institute of Technology, U.S.A., in whose laboratories this work was carried out.

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LEAK DETECTION IN UNDERGROUND GAS CABLES, OR PIPES WITH RADIOACTIVE TRACERS AND HALOGEN GASES*

Leak detection in underground gas compression cables is a difficult and lengthy operation and is carried out with oxygen

or air bubbles. Two new methods have been developed, which in combination make the operation much quicker and simpler.

Radioactive gas is injected first into the middle joint of the cable. It flows towards the leak; the direction is determined by Geiger-Müller counters placed one each side of the injection point, measuring γ radiation across the sheath. The procedure is repeated at the middle joint of the cable half containing the leak. By such successive manipulation the leak is located between two joints. It is difficult to obtain a suitable tracer in gas form, therefore solid NH_4Br is irradiated, from that substance liquid C_2H_5Br is prepared and this in turn is evaporated in a bottle used for the injections. The radioactive isotope is Br^{82} with a half-life time of 34hrs. The activities used in this operation are of the order of 5—50 microcuries and the mass of NH_4Br is of the order of 5—50 g. No health hazards are incurred and no damage is done to the insulation.

The exact position of the leak between two joints is determined by filling the cable gas pipe with CCl_2F_2 . This gas leaks to the surface above the leak, only a small part of it being absorbed by soil and/or moisture. The gas and the leak position is detected by the extremely sensitive halogen gas leak detector² (sensitivity 1 part in a million).

These methods can be also used in subterranean gas pipes. Further radioactive tracers are suitable for the determination of gas flows of extremely small velocities.

This technique was developed for Enfield Cables Ltd., Brimsdown, Middx., England.

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* Received June 1951

A NOTE ON THE EXTENSION OF POISEUILLE'S EQUATION TO NON-NEWTONIAN LIQUIDS*

In some non-Newtonian solutions of polymers, the dependence of the overall viscosity on the gradient may be described by a series of even powers of the gradient:

$$\eta_q = \eta_0 (1 - aq^2 + bq^4 - cq^6 \dots) \quad (1)$$

where η_q is the viscosity at the velocity gradient q and η_0 — the viscosity at zero velocity gradient.

The series development of the stress component of viscous flow for non-Newtonian liquids in general has been investigated by Reiner¹. Recently, W. Kuhn and H. Kuhn² have shown that polymers of high "inner viscosity" obey equation (1); they have deduced the coefficients of the powers of q from molecular parameters. In the case discussed by these authors, the non-Newtonian behaviour is a property of the molecule and is exhibited even at very high dilutions, as opposed to "structural viscosity" which is a property of the system and vanishes at high dilutions.

The variable viscosity η_q is readily measured in a Couette viscometer. The viscosity data obtained in a capillary viscometer, on the other hand, are not directly amenable to interpretation, as the gradient in the capillary is not constant but varies from zero in the centre to a maximum near the walls.

The present note tries to evaluate η_0 and also a , the first parameter in the expansion of (1) from measurements in capillary viscometers.

In the special case of sufficiently small a and q values, the series reduces to the first two terms

$$\eta_q = \eta_0 (1 - aq^2) \quad (2)$$

In a capillary viscometer, we have $q = dv/dr$, where v is the velocity of flow at the distance r from the centre of the

capillary. For any "telescopic" layer, the condition of stationary flow is

$$\eta_q q = -Pr/2L \quad (3)$$

P being the external pressure, L the length of the capillary.

Introducing into (3) the value of η_q from (2), we obtain:

$$\eta_0 (1 - aq^2) q = -Pr/2L \quad (4)$$

and differentiating with respect to r :

$$dq/dr (3aq^2\eta_0 - \eta_0) = P/2Lq \quad (5)$$

which leads on integration, to

$$\frac{3}{4}aq^4\eta_0 - \frac{1}{2}\eta_0 q^2 = Pv/2L - Pv_{\max}/2L \quad (6)$$

The integration constant is obtained from the following considerations: although the non-Newtonian flow distorts the parabolic distribution of velocity in the capillary, the rotational symmetry is retained, i.e. in the centre of the capillary, $v = v_{\max}$ and $q = 0$.

From equation (6), we obtain by solving and developing in series:

$$q = \sqrt{P\eta_0/L(v_{\max} - v) + 3aP^2/2\eta_0^2L^2(v_{\max} - v)^2} \quad (7)$$

For $a=0$, this gives the Newtonian distribution of the velocity gradient.

The further integration of (7), after developing the square root in a series and

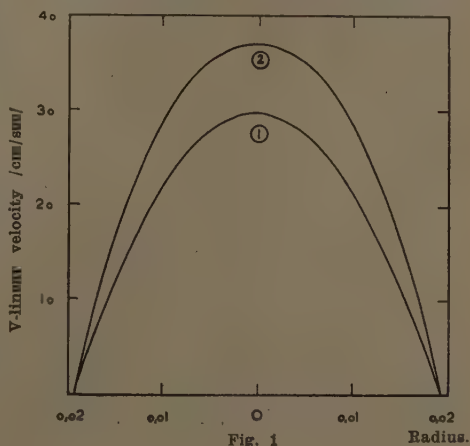


Fig. 1

* Received Oct. 1950

taking into account that for $r=R$ (R = radius of the capillary), $v=0$, gives

$$r^2 = 4\eta_0 L / P(v_{\max} - v) [1 - (v_{\max} - v) a P / 4\eta_0 L]^2$$

$$R^2 = 4\eta_0 L v_{\max} / P(1 - a P v_{\max} / 4\eta_0 L)^2 \quad (8)$$

Equation (8) represents the velocity distribution of a non-Newtonian solution in a capillary.

Fig. 1 shows the flow profile of a Non-Newtonian (2), as compared with a Newtonian (1), Liquid, in a capillary.

($\eta_0 = 6 \cdot 10^{-2}$, $a = 10^{-8}$, $R = 0.0177$ cm, $P = 10^5$ dyn/cm², $q_{\max} = 3 \cdot 10^{-3}$)

Equation (9) gives directly the amount Q of liquid flowing through the capillary in unit time:

$$Q = \pi \int r^2 dr = 4\eta_0 L \pi v_{\max}^2 / P(\frac{1}{2} + a P v_{\max} / 3\eta_0 L) \quad (9)$$

Introducing the value of $v_{\max}$ from (8), we finally obtain:

$$Q = \pi P R^4 / 8\eta_0 L (1 + a P^2 R^2 / 3\eta_0^2 L^2) \quad (10)$$

Let the volume of liquid flowing through the capillary of the viscometer be Q' , and the time of flow t , then $Q'/t = Q$, and

$$Q'/t = \pi P R^4 / 8\eta_0 L (1 + a P^2 R^2 / 3\eta_0^2 L^2) \quad (10')$$

If the flow time of the pure solvent of viscosity η_s is t_s in the same viscometer and at the same pressure, then

$$Q'/t_s = \pi P R^4 / 8\eta_s L \quad (11)$$

Dividing (10') by (11) we find:

$$\frac{t_s}{t} = \frac{\eta_s}{\eta_0} \left(1 + \frac{a P^2 R^2}{3\eta_0^2 L^2} \right) \quad (12)$$

Hence, by a series of measurements of the time of flow in viscometers of different radii or in the same viscometer but under different pressures, the true viscosity η_0 at gradient zero and the parameter a may be obtained.

The non-Newtonian flow of polymethacrylic acid of high molecular weight at 50% ionization was investigated in this laboratory. Even at very high dilutions (using various capillary viscometers), the solutions exhibited a pronounced dependence of viscosity on the velocity gradient.

The measurements were carried out in Ostwald-Fenske viscometers (A.S.T.M. D-445) of radii 0.0225, 0.033 and 0.050 cm., under a pressure head of $8.8 \cdot 10^5$ dyne/cm². The ratios t_s/t at two different concentrations

of the polymer (expressed in base mole per litre) was plotted against the square of the capillary radius. The true value of η_0 is then obtained from the intercept of the curves at $R^2=0$, and the value of a from the slope of these curves, in accordance with equation (12).

In the following Table, these η_0 values are compared with the η' values obtained from the ordinary Poiseuille equation (instead of equation (10)).

Viscosity data obtained in a capillary viscometer are not generally amenable to interpretation when the liquid tested is non-Newtonian in character, as the gradient varies from zero at the centre of the tube to a maximum near the walls.

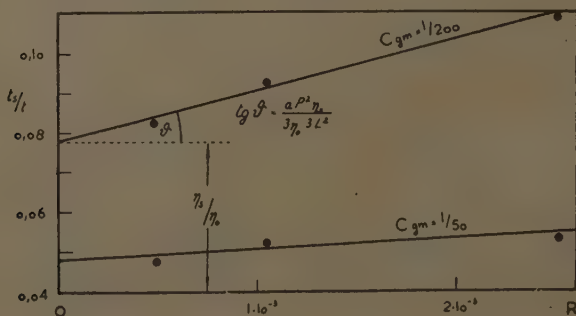


Fig. 2

The following analysis is found to be of assistance.

Expressing the viscosity at a shear rate by means of the first two terms of the

even power series as investigated by Reiner¹, we write $\eta_q = \eta_0 (1 - aq^2)$ where $q = dv/dr$ and $q\eta_q = -Pr/2L$, using the customary notation.

TABLE
Viscosity Measurement of Polymethacrylic Acid ($Z=5.600$; $t=30^\circ$).
 $C_{gm} = 1/50$.

R(cm)	R^2	t_s (sec)	t (sec)	t_s/t	η' (c.p.)	η_0
0.05	$2.5 \cdot 10^{-3}$	8.2	151	0.0543	14.7	
0.0325	$1.06 \cdot 10^{-3}$	48.7	935.8	0.0521	15.4	
0.0225	$5.07 \cdot 10^{-4}$	203.1	4090	0.0496	16.1	

16.5

$C_{gm} = 1/200$

0.05	$2.5 \cdot 10^{-3}$	8.2	74.8	0.1096	7.3	
0.0325	$1.06 \cdot 10^{-3}$	48.7	527	0.092	8.66	
0.0225	$5.07 \cdot 10^{-4}$	203.1	2407	0.0844	9.5	

10.2

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A TENTATIVE EXPLANATION OF THE "WEISSENBERG EFFECT" IN LATEX SOLUTIONS*

Shearing motion produces in certain liquids not only shearing stresses but also stresses in other directions. This effect described by Garner and Nissan¹ and Weissenberg² was treated theoretically by Oldroyd³, Reiner⁴ and Rivlin⁵. It will be shown that the last two theories are an oversimplification and do not describe the more complicated behaviour of slightly vulcanized latex solutions.

The instrument constructed for this investigation (see fig. 1) ensures a cylindrical field with only small end effects, which would tend to generate secondary motions constantly transferring liquids from fields of one velocity gradient to another. The outer cylinder is rotated; the inner stationary cylinder has slots through

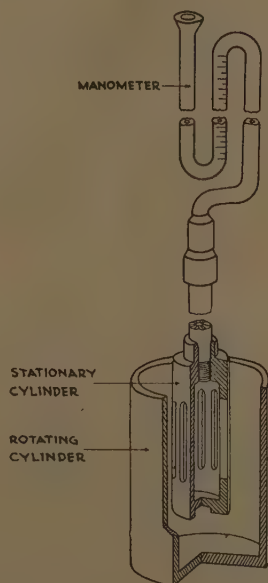


Fig 1

* Received September 1950

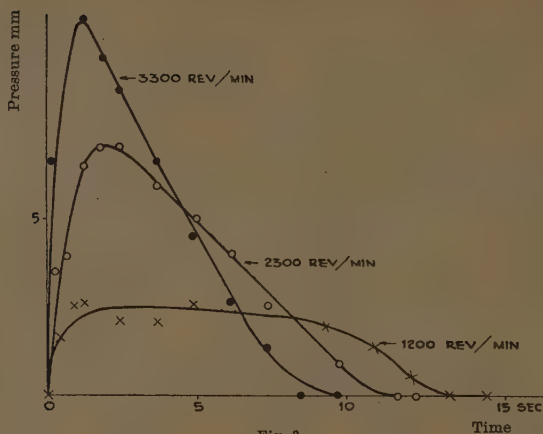


Fig. 2

which the liquid can flow. Tangential forces between the cylinders result in a positive pressure within the inner cylinder. This pressure is transmitted by means of air through a pipe to a glass manometer consisting of an alcohol-filled U-tube.

The results obtained with slightly vulcanized latex solutions and constant rotation velocity are presented graphically in Fig. 2. The pressure rises from zero to maximum value and drops again nearly

to zero. The increase in pressure does not reappear when rotation is interrupted and started again after a short interval. Only after a recovery time of several hours can the initial phenomenon be observed again. The maximum pressure reached increases with the rotation velocity.

This phenomenon can be interpreted on the basis of the following model: at the start, the molecules form relatively large aggregates of random structure (Fig. 3).

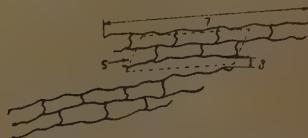
POLYISOPRENE CHAIN
S-S BRIDGES
molecule of a slightly vulcanized rubber



oriented structure



structure of quiescent liquid



relative movement of vulcanized molecules in oriented structure

Fig. 3

The time necessary for their formation being of the order of magnitude of 3 to 24 hours, i.e. the time necessary far "recovery". When the liquid is subjected to a rotary movement, some of the aggregates adhere to the solid surfaces and arrange themselves in the direction of the rotary movement, in the way in which macaroni twist around a turning fork. This arrangement of the shearing aggregates produces tangential and radial forces causing the liquid to raise the pressure in the inner cylinder. (Only the tangential forces are considered here).

If the velocity gradient increases, the degree of this orientation should also increase. This degree of orientation is measured for sufficiently low gradients by the maximal increase in pressure as depicted in Fig. 4.

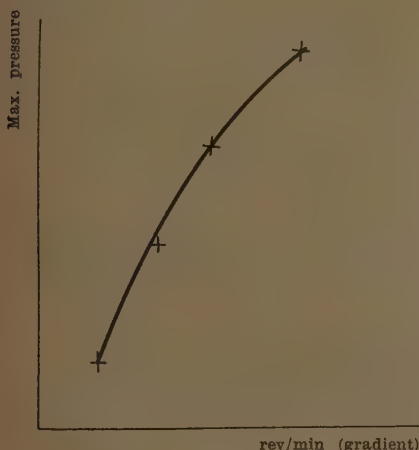


Fig. 4

As orientation increases, however, another opposing process becomes operative. The shearing stresses developing in the oriented structure tend to overcome the van-der-Waals forces and thus to destroy the aggregates. With the velocity gradient used in these experiments, this degradation process is much slower than the orientation, although much faster than the building-up of the aggregates from their individual elements in solution.

For the breakdown of the oriented structure, the following mechanical model is suggested. Each bundle of oriented molecules can perform two viscous movements: it can participate in the rotation of the liquid as a whole, but can also maintain an interval flow of the constituent elements against each other. When the bundle lies across a velocity gradient, sufficient shear stresses develop to produce a relative movement of the constituent in the molecular aggregate. Eventually, an increasing number of bundles disintegrate. When this effect has reached its final stage, the pressure in the inner cylinder falls to zero.

It is possible therefore to speak of two viscosities: the overall viscosity, as measured in the usual viscosimeter, and an "interior viscosity" determined by the van-der-Waals interaction between the constituent elements of the aggregate structure.

The flow against the "interior viscosity" may be described as follows:

Let the bulk viscosity of the solution be η_s and the interior viscosity η_i . Let us isolate a pair of molecules of chain length L lying one upon the other, but in different streamline levels, with a velocity gradient of $\partial v / \partial r$. Let the distance between the molecules be δ . Then the difference in the velocity of the solution in the two levels will be $|(\partial v / \partial r) \delta|$. The shear stress (F_1) of the surrounding liquid will be:

$$F_1 = \eta_s \frac{\partial v}{\partial r} S$$

where S is the surface of molecular contact.

On the other hand, the force developed between the two neighbouring molecules (F_2) is

$$F_2 = \eta_i \frac{v_m}{\delta} S$$

where v_m is the relative velocity of the molecules. At constant flow velocity, the forces F_1 and F_2 become equal and

$$v_m = \frac{\eta_s}{\eta_i} \delta \frac{\partial v}{\partial r}$$

It is assumed that the structure is destroyed when the pair of molecules considered have moved, relatively to each other, all along their length and have separated entirely.

If the mean molecular length is L , the time (T) necessary for the process is

$$T = \frac{L}{v_m} = \frac{\eta_1}{\eta_s} \frac{L}{\delta} \cdot \frac{I}{\left(\frac{\partial \nu}{\partial r}\right)}$$

An inspection of Fig. 2 shows that the decrease of the pressure with time is indeed linear. This can be taken as an indication of a constant viscous flow in the structure.

It might be expected that η_1 , η_s , $\frac{L}{\delta}$ are constants; hence $T(\partial \nu / \partial r)$ should be constant, which is borne out by the experiment. (For a degree of polymerization of 10,000, η_1 is of the order of magnitude of 10 poise).

The authors are greatly indebted to Prof. M. Reiner for his constant interest in this investigation and his helpful suggestions.

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REAL SOLUTIONS OF POLYELECTROLYTES*

1. *Thermodynamic considerations.* The dynamic behavior of water-soluble polyelectrolytes, the change of molecular shape with ionization¹, and the inherent

contractility of mechano-chemical systems² may all be attributed to the electrostatic field energy of the ionized polymolecules. The latter may be determined experimentally by means of the potentiometric titration of acidic or basic polymers, as well as of acid-base copolymers. It will be shown that the potentiometric titration provides a thermodynamically justified method for the determination of the inner electrostatic field energy.

For the thermodynamic evaluation of the potentiometric behavior of solutions of polyacids and polybases, these solutions are regarded as heterogeneous system composed of a molecular phase (m) and a solvent phase (s)³. Furthermore, let the polymolecule, constituting a single molecular phase, carry P ionizable groups of which ν are ionized, so that the degree of ionization $\alpha = \nu/P$. Denoting the thermodynamic potentials of the protons distributed between the molecular and the solvent phases by μ_H^m and μ_H^s respectively, the condition for equilibrium of the protons between the phases is

$$\mu_H^m = \mu_H^s \quad (1)$$

The activity of the hydrogen ions in solution being $[H]$, their thermodynamic potential is given by

$$\mu_H^s = \mu_H^0 + kT \ln [H] \quad (2)$$

The thermodynamic potential μ_H^m of the protons in the molecular phase is obtained from the expression

$$\mu_H^m = \partial F^m / \partial (P - \nu) = - \partial F^m / \partial \nu \quad (3)$$

where F^m denotes the free energy of the molecular phase and $(P - \nu)$ is the number of undissociated groups, corresponding to the number of protons in this phase. The free energy may be divided into two components

$$F^m = F_o^m + F_e^m \quad (4)$$

in which F_o^m is derived from the general properties of the solution and is independ-

* Received September 1950

ent of the degree of ionization, while F_e^m is the electrical contribution to the free energy. F_e^m is further separable into an inner energy term and an entropy component:

$$F_e^m = E_e^m - TS_e^m \quad (5)$$

The inner electrostatic energy is composed of the field energy ϵ_v of the molecules carrying v elementary charges, and the work $v\epsilon_0$ done on the polymolecule by dissociation of the v groups; ϵ_0 is the work required for dissociation of a single ionizable group, independent of the field energy. Hence

$$E_e^m = \epsilon_v + v\epsilon_0 \quad (6)$$

The electrical entropy contribution comprises the mixing entropy of the ionized and undissociated groups

$$S_e^m = k \left\{ v \ln \left[\frac{v}{P} \right] + (P-v) \ln \left[\frac{P-v}{P} \right] \right\} \quad (7)$$

v/P and $(P-v)/P$ being the mole fractions in the molecular phase of the ionized and undissociated groups respectively.

From the above considerations, we obtain the thermodynamic potential of the hydrogen ions in the molecular phase:

$$\begin{aligned} \mu_H^m &= -\partial F^m / \partial v \\ &= -\partial \epsilon_v / \partial v - \epsilon_0 + kT \ln [v / (P-v)] \end{aligned} \quad (8)$$

and by equating μ_H^m to μ_H^s according to (1):

$$\begin{aligned} \mu_H^0 + kT \ln [H] \\ = -\partial \epsilon_v / \partial v - \epsilon_0 + kT \ln [v / (P-v)] \end{aligned} \quad (9)$$

We now identify $\mu_H^0 + \epsilon_0$ with the change in standard free energy accompanying the ionization of a single proton from an isolated group, independent of the electrical field influence. $\mu_H^0 + \epsilon_0$ therefore determines the inherent dissociation constant (K_0) of a single group according to the thermodynamic relation

$$\mu_H^0 + \epsilon_0 = -kT \ln K_0 \quad (10)$$

Combining the last equations (using pH and pK notations) we obtain:

$$\begin{aligned} pH &= pK_0 - \log [(P-v)/v] \\ &\quad + (0.4343/kT) \partial \epsilon_v / \partial v \end{aligned} \quad (11)$$

$$\begin{aligned} \text{or } pH &= pK_0 - \log [(1-\alpha)/\alpha] \\ &\quad + (0.4343/kT) \partial \epsilon_v / \partial v \end{aligned} \quad (11a)$$

Formula (11) has previously been derived from kinetic considerations⁴. If pH, pK₀ and the degree of ionization α are known, the partial differential coefficient of the field energy $\partial \epsilon_v / \partial v$ is obtained directly from (11). A plot of $\partial \epsilon_v / \partial v$ versus the number of ionized groups per molecule v , finally permits the evaluation of the electrical field energy ϵ_v .

2. *The theoretical evaluation of the field energy.* The theoretical evaluation of the field energy is based on the following assumptions: (a) the ionized polyelectrolyte molecules retain the randomly kinked configurations of the polymer coil, though more extended configurations are favored at higher degrees of ionization; (b) the electric charge is distributed evenly over the molecular chain¹; and, (c) the macromolecule is sufficiently loose to be freely permeated by small ions.

Hence, Debye atmospheres, consisting of the free gegen-ions and of other free ions in solution are built up around the fixed charges carried by the polymolecule, both inside and outside the macromolecular coil. The polyelectrolyte field is sufficiently strong to attract selectively the ions of opposite sign and to repel those of equal sign; therefore, in the determination of the radius $1/\kappa$ of the Debye atmospheres the ions of opposite sign to the fixed charges play a predominant part⁵.

The rather lengthy calculations leading to the theoretical evaluation of the inner field energy will be given elsewhere. A simple approximation for the case of a real polymer molecule in a field of definite ionic strength is given by

$$\epsilon_v = (\nu^2 \epsilon^2 / Dh) \ln(1 + 6h / \kappa NA^2) \quad (12)$$

h = the mean end-to-end distance of the molecule

D = the dielectric constant of the medium

ϵ = the charge of the electron

N = the number of statistical elements per molecule

A = the hydrodynamic length of a statistical element

The theoretical evaluation of the energy by means of equation (12) requires an independent knowledge of the mean end-to-end distance of the molecule. This may be readily deduced from viscometric measurements according to the well-known relationship

$$\left(\frac{\eta_{sp}}{c} \right)_{c \rightarrow 0} = K_m \bar{h}^2 \quad (13)$$

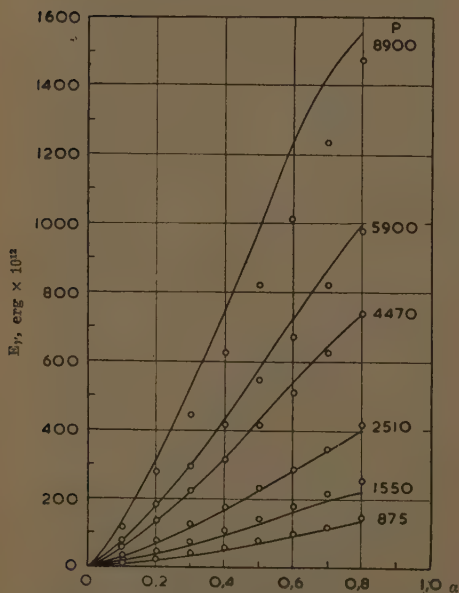


Fig. 1. — Electrostatic energy (ϵ_v) of polymethacrylic acid in 1/100 base-molar aqueous solutions, versus the degree of ionization α . The curves represent fractions of degree of polymerization P . Solid lines calculated values of ϵ_v from equation (12); points—experimental values of ϵ_v from equation (11 a).

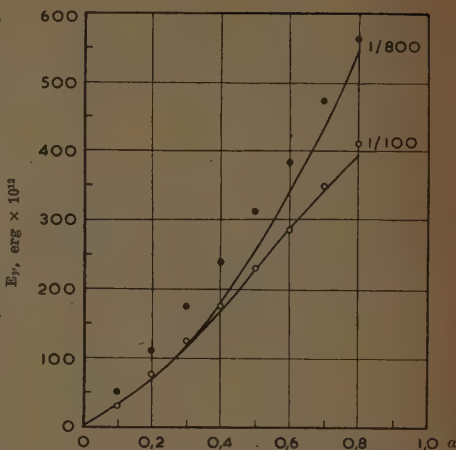


Fig. 2. — Electrostatic energy (ϵ_v) of polymethacrylic acid in 1/100 and 1/800 base-molar aqueous solutions, versus the degree of ionization α . The degree of polymerization $P=2510$. Solid lines—calculated values of ϵ_v from equation (12); points — experimental values of ϵ_v from equation (11 a).

where K_m is a parameter determined by the molecular weight and the molecular geometry of the polymolecule⁹.

3. *The field energy of ionized poly-electrolytes.* Potentiometric titrations and viscometric measurements were undertaken with well-defined fractions of polymethacrylic acid of degrees of polymerization ranging from 850 to 8900⁷. The remarkable fact found was that at equal concentrations in base moles, the titration curves are independent of the molecular weight. In terms of equation (11) this means that $\partial \epsilon_v / \partial \nu$ is independent of the molecular weight. On the other hand, the titration is greatly dependent on the ionic strength, $\partial \epsilon_v / \partial \nu$ decreasing with increasing ionic strength. The field energy, obtained by graphical integration of $\partial \epsilon_v / \partial \nu$ over ν is dependent on the molecular weight, ϵ_v increasing with the degree of polymerization for a given α .

In Fig. 1 are given the values of ϵ_v as a function of α for various fractions of

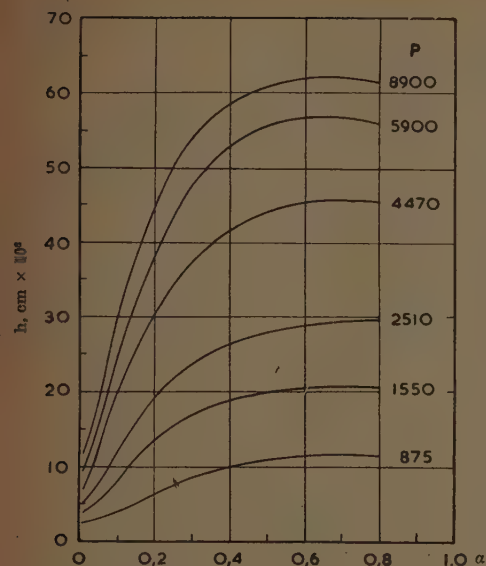


Fig. 3. — Mean end-to-end distance h of polymethacrylic acid molecules in 1/100 base molar aqueous solutions versus the degree of ionization α ; P — the degree of polymerization of various fractions.

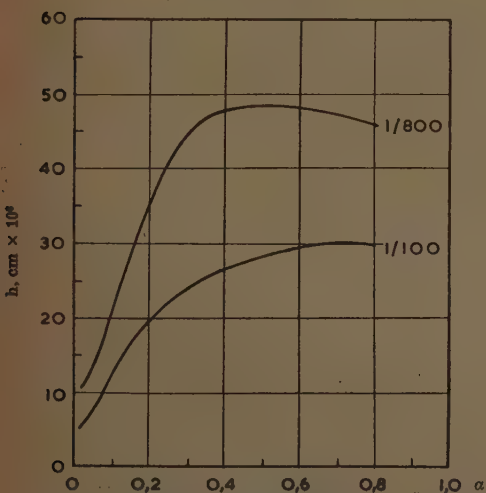


Fig. 4. — Mean end-to-end distances h of polymethacrylic acid molecules in 1/100 and 1/800 base molar aqueous solutions, versus the degree of ionization α . The degree of polymerization $P=2510$.

polymethacrylic acid at 1/100 base-molar concentration, while Fig. 2 represents the dependence of ϵ_p on the ionic strength. The end-to-end distances h obtained from viscometric measurements at degrees of ionization α and at concentrations corresponding to the potentiometric titration are given in Figs. 3 and 4. The solid lines of Figs. 1 and 2 are the calculated values of ϵ_p from equation (12) by using h values given in Figs. 3 and 4. The points in Fig. 1 and 2 are the experimental energy values obtained from the potentiometric titration. The agreement between theory and experiment is as good as might be expected from the model and gives substantial support to the theory.

The knowledge of the field energy of polyelectrolytes in solutions of finite ionic strength permits the interpretation of the colligative properties of these solutions, such as the osmotic pressure and the swelling pressures operative in polyelectrolyte mechano-chemical systems.

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2,3,6,7,-DIBENZOTROPONE*

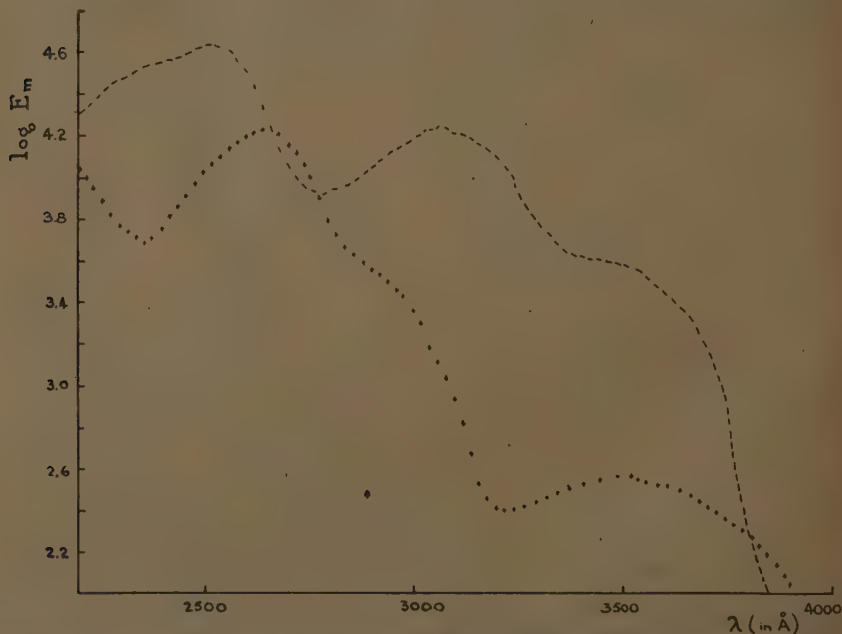
Tropone (I) is interesting as the parent substance of a number of natural products derived from its hydroxy-derivative (tropolone, II)¹, and also from the theoretical point of view. Dewar² has predicted that the cycloheptatriene system contained in (I) and (II) would resemble an aromatic ring, so that (I) should rather be "cycloheptatrienylum oxide" (Ia) than a ketone. Indeed, the properties of tropone, recently synthesized by Dauben and Ringold³, and Doering and Detert⁴, prove that (Ia) is a more adequate formula than (I): the substance forms salts, couples with benzenediazonium chloride and is substituted by bromine, but gives none of the usual carbonyl derivatives. The carbonyl frequency lies at 1638 cm^{-1} , indicating

a very high degree of ionic character of the double bond.

It may be interesting to report on the properties of the benzo-derivatives of (I), e.g. 2,3,6,7-dibenzo-2,4,6-cycloheptatrienone (V), which have been studied in connection with another problem. (V) could easily be prepared from 2,3,6,7-dibenzo-2,6-cycloheptadienone (III)⁵ by successive treatment with N-bromosuccinimide (yielding 2,3,6,7-dibenzo-4-bromo-2,6-cycloheptadienone (IV) and pyridine. (IV) was recrystallised from petroleum ether and had m.p. 185° . [dec] (V) chrystallised from the same solvent and melted at $90-91^{\circ}$. (*Anal.* Calcd. for $C_{15}H_{10}O$: C, 87.4; H, 4.9. Found: C, 87.5; H, 4.6).

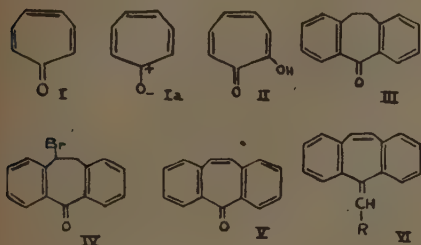
The behaviour of (V) is entirely different from that of (I). It does not give salts with hydrochloric, hydrobromic or picric acid but a normal 2,4-dinitrophe-

* Received May 1951



Absorption of the iso octane solution of 2,3,6,7-dibenzo-2,4,6-cycloheptatrienone (— —) and of 2,3,6,7-dibenzo-2,6-cycloheptadienone (...

nylhydrazone (m.p. 252-254° [dec.] [from ethyl acetate-ethanol]). Its reaction with Grignard compounds is normal⁸. The infrared spectrum shows the carbonyl frequency at 1660 cm^{-1} ⁷, i.e. approximately at the same wave-length as in benzophenone⁸.



In the fulvene series, it has been shown before^{9,10} that the annellation of benzene rings reduces progressively the characteristics of the cross-conjugated system. This phenomenon is even more pronounced in the transition from (I) to (V)¹¹. In a study, to be published elsewhere⁸, it will be shown that also the "heptafulvenes" (VI) do not have the physical and chemical properties which the theory of molecular orbitals predicts, and that the reason for this discrepancy is most probably lack of planarity in the seven-membered ring. In (I), the planar structure is obviously maintained by the conjugating power of the double bonds, which in (V) is suppressed by their participation in the annellated aromatic rings. The spectra of (III) and (V) are reproduced in Fig. 1.

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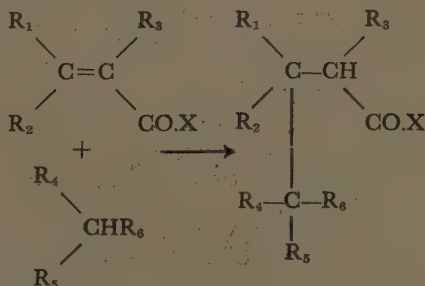
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11. In this respect, the 4,5-benzo-2,4,6-cycloheptatrienones of THIELE and WEITZ (*Annalen*, 1910, 377, 77.) deserve a systematic study; equally the 2,3,4,5-dibenzo-2,4,6-cycloheptatrienone of Cook and co-workers (*J. Chem. Soc.*, 1947, 746; *Nature*, 1948, 162, 692).

ON THE STERIC COURSE OF THE MICHAEL CONDENSATION*

In the alkali-catalysed addition of reactive methylene or methine compounds to α , β -unsaturated carbonyl compounds or esters, a number of centres of asymmetry (up to 3) can be formed, as can be seen from the following general formulation:



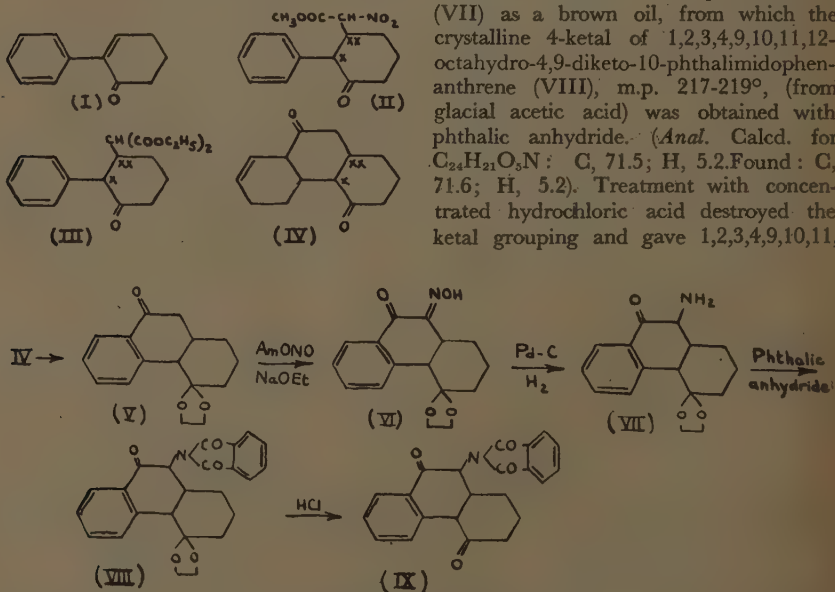
* Received May 1951

However, no systematic work seems to have been done¹ on the steric course which this condensation reaction takes, and, indeed, it would be difficult to establish absolute (or even relative) steric relationships between starting materials and final products. It may, of course, be assumed, that the configuration of the α -carbon atom in the resulting carbonyl compound or ester will be determined not only by the steric course of the reaction, but also by the enolising ability of the alkaline catalyst (successive enolisation and ketisation tending always to establish the most stable configuration on the α -carbon atom). However, this argument cannot be applied to the β - or γ -carbon atoms of the reaction product (when $R_4, R_5, R_6 \neq H$).

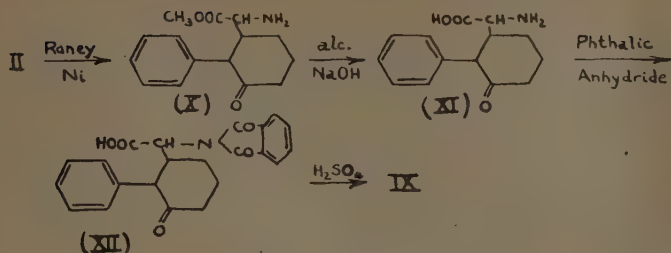
A case particularly suitable for a stereochemical study of this reaction appears to be provided in the Michael condensation of cyclic α, β -unsaturated

ketones, such as 2-phenyl-*cyclohex*-2-enone (I)^{2, 3, 4}. It has been shown that this ketone adds methyl nitroacetate to give methyl 3-keto-2-phenyl*cyclohexyl*- α -nitroacetate (II), and ethyl malonate to give ethyl 3-keto-2-phenyl*cyclohexyl* malonate (III), from which by hydrolysis, half-decarboxylation and cyclisation, 1, 2, 3, 4, 9, 10, 11, 12-octahydro-4,9-diketo-phenanthrene (IV) is available. It will be shown that the steric course of these two Michael condensations is identical.

When the 4-ethylene glycol ketal (V) of (IV) was treated with amyl nitrite in the presence of sodium ethoxide, the 4-ketal of 1,2,3,4,9,10,11,12-octahydro-4,9-diketo-10-oximinophenanthrene (VI) was formed, m.p. 182-184° (dec.) (from ethanol). (*Anal.* Calcd. for $C_{16}H_{17}O_4N$: C, 66.9; H, 5.9. Found: C, 66.8; H, 5.7). Catalytic reduction of (VI) in alcoholic solution (10% palladium-charcoal) yielded the 4-ketal of 1,2,3,4,9,10,11,12-octahydro-4,9-diketo-10-aminophenanthrene (VII) as a brown oil, from which the crystalline 4-ketal of 1,2,3,4,9,10,11,12-octahydro-4,9-diketo-10-phthalimidophenanthrene (VIII), m.p. 217-219°, (from glacial acetic acid) was obtained with phthalic anhydride. (*Anal.* Calcd. for $C_{24}H_{21}O_5N$: C, 71.5; H, 5.2. Found: C, 71.6; H, 5.2). Treatment with concentrated hydrochloric acid destroyed the ketal grouping and gave 1,2,3,4,9,10,11,



Reaction Scheme I.



12-octahydro-4,9-diketo-10-phthalinidophenanthrene (IX), m.p. 186-187° (from acetic acid or ethanol). (*Anal.* Calcd. for $C_{22}H_{17}O_4N$: C, 73.5; H, 4.7. Found: C, 73.5; H, 4.4). (Reaction Scheme I).

Reduction of (II) at 100° and 120 atmospheres (Raney nickel), gave the oily methyl (3-keto-2-phenylcyclohexyl)-aminoacetate (X); the corresponding amino-acid (XI) had m.p. 183-186° (dec.) (from water). (*Anal.* Calcd. for $C_{14}H_{17}O_3N$: C, 68.0; H, 6.9. Found: C, 68.2; H, 6.8). Fusion of (XI) with an equivalent amount of phthalic anhydride yielded (3-keto-2-phenylcyclohexyl)-phthalimidoacetic acid (XII), mp. 227° (from ethanol). (*Anal.* Calcd. for $C_{22}H_{19}O_5N$: C, 70.0; H, 5.0. Found: C, 69.8; H, 5.1). Its cyclisation by means of sulphuric acid yielded a product identical in physical properties and infrared absorption spectrum with (IX). (Reaction Scheme II)

The configuration created by the Michael condensations of (I) at the new asymmetric centres (which are marked by asterisks in formulae (II), (III), (IV)), is therefore identical in the two cases studied. Under no circumstances can the configuration at C** change in the course of the reactions applied. The nature of the latter makes it also highly improbable that at any one step in the above two Reaction Schemes, complete inversion of configuration occurs at the C* carbon atoms; at least, the "degree of coincidence"¹⁵ which would have to be postulated in order to explain the

results of this investigation otherwise, would be extremely improbable.

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THE MECHANISM OF LOW TEMPERATURE PHOTOCHROMY IN THE BIANTHRONE SERIES *

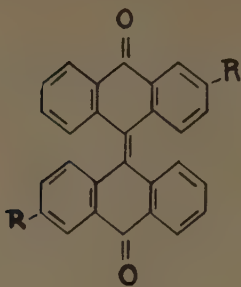
During an investigation of the behaviour of thermochromic compounds at low temperature which led to the discovery of low temperature thermochromy¹, a new effect of photochromy has been observed². The main characteristics of this phenomenon are as follows:

Solutions of bianthrone (I, II, III) or of xanthylideneanthrone (IV) when irra-

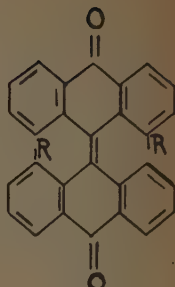
* Received May 1951



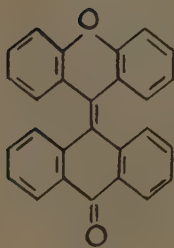
I



II



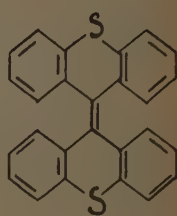
III



IV



V



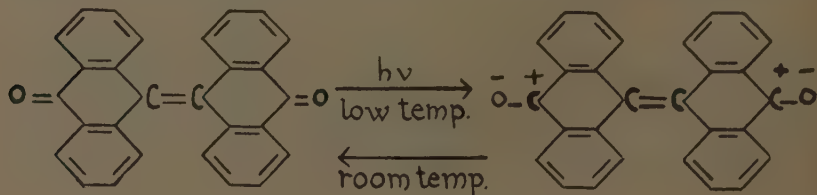
VI

diated for a short time at -50° to -66°C , develop colours, which persist even after irradiation has been interrupted, as long as the solutions are kept at the low temperature. On heating, the induced colours begin to fade and disappear when the solutions reach room temperature. There is no chemical change involved in this process, which can be repeated many times with the same solution, provided that the latter is kept free of oxygen and is not irradiated unless cooled first.

The fact that also solutions of substituted bianthrone (III) which are not

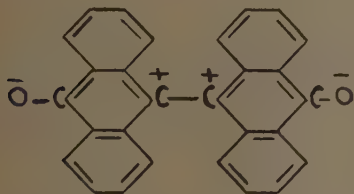
thermochromic³), show photochromy, proves that the mechanism of the latter is distinct from the mechanism by which thermochemistry is produced.

It has further been shown that solutions of dixanthylene (V) or dithioxanthylene (VI), though strongly thermo-chromic⁴), do not show the phenomenon of photochromy. Since compounds (V) and (VI) differ from (I), (II), (III) and (IV) only in that they do not contain a carbonyl group, the conclusion seems justified that the carbonyl group is the carrier of the photochromy effect. The latter could thus be explained by the fol-



lowig mechanism: At low temperature, the carbonyl groups terminating the extended conjugated system absorb a quantum of light, yielding an ionic coloured molecular species which is stable at low temperature.

When the solution is warmed, the coloured ions lose slowly the absorbed light energy, e.g. by collision with other biathrone molecules or with molecules of the solvent, and regenerate the original non-ionised system. It is understood that the formulation of the ionised molecule has only schematic value; it may well be that it is stabilised by resonance with a form such as



in which the presence of the anthracenoid skeleton would contribute to the stability of the molecule.

A full report will be published elsewhere.

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THE INFLUENCE OF TWO GERMINATION INHIBITORS (COUMARIN AND 2,4-D) ON GERMINATION IN CONJUNCTION WITH THIOUREA AND CYSTEINE *

From the great number of known germination inhibitors reviewed by Evenari¹, two are of special interest: 2,4-D, because it is of great practical importance, and coumarin, because it makes light indifferent lettuce seeds sensitive, besides being a quite effective germination inhibitor (Evenari^{1, 2, 3}).

These two inhibitors were tested together in order to determine whether there was a synergistic or antagonistic effect. In addition each one was used in conjunction with thiourea and with cysteine. We chose thiourea, because it is known as a germination stimulant which, in addition, has an effect on lettuce seed opposite to that of coumarin, i.e. it abolishes the light sensitivity of light sensitive seeds. Cysteine was chosen in order to determine whether there was any relation between germination inhibition and possible enzymes containing sulphhydryl groups.

The germination tests were carried out as described by Evenari² at a constant temperature of 26°C. in the dark. Each substance was first tested separately and its inhibitory effect noted. The numerical sum of the inhibition obtained by any two substances under consideration is termed the theoretical inhibition. The same substances are then tested in conjunction and the actual inhibition found is determined. This is the experimental inhibition.

As normal germination was never less than 97%, all figures given are related to 100% control germination.

Experiments on Wheat

2,4-D and Coumarin

For all concentrations of 2,4-D and coumarin tested (2,4-D 0.45-1.13×10⁻³M

* Received September 1950

TABLE I.

Coumarin concn. $\times 10^{-3}M$	1.03	1.37	1.7	2.06
Theoretical	95	83 ± 5	79 ± 6	74.5 ± 5.5
Experimental	85	64 ± 10	57 ± 6	53 ± 11

TABLE II.

2,4-D concn. $\times 10^{-3}M$	0.45	0.68	0.91	1.13
Theoretical	83	5	83	81
S.D			10.4	6
Experimental	89	5	86	85
S.D			8	5

and coumarin $1.03\text{--}2.06 \times 10^{-3}M$) the experimentally found germination was found to be about 10-20% lower than would be theoretically expected. Evidently there is some form of synergism of the two substances.

Coumarin and Thiourea

The thiourea concentration was kept constant at $19.5 \times 10^{-3}M$ and the coumarin concentration varied. The results are given in attached Graph I and Table I.

Although the differences between the two values are not very great, it appears that there is a small but distinct depression of germination if the two substances are applied together.

2,4-D and Thiourea

Experiments parallel to those for coumarin, with thiourea constant at $19.5 \times 10^{-3}M$, were carried out (Table II).

As far as any significance can be attached to the slight differences between

the theoretical and experimental curves, a stimulation of germination appears to be caused by the addition of thiourea to 2,4-D. It may be pointed out here that thiourea alone does not cause any germination inhibition at the concentrations used.

Coumarin and Cysteine

Coumarin at concentration of $1.03\text{--}2.06 \times 10^{-3}M$ and Cysteine at concentrations of $8.3 \times 10^{-3}M$ when used together showed no difference between theoretical and experimental values.

2,4-D and Cysteine

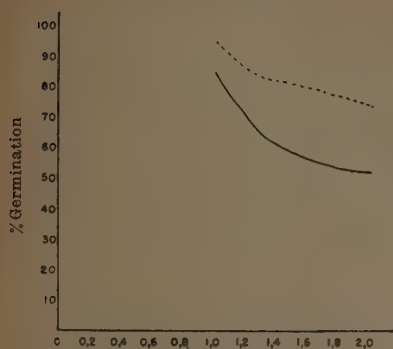
Cysteine at a concentration of $8.3 \times 10^{-3}M$ in conjunction with 2,4-D of $0.45\text{--}1.13 \times 10^{-3}M$ gave no significant difference between theoretical and experimentally found germination percentages.

At a Cysteine concentration of $16.6 \times 10^{-3}M$ a very marked difference between theoretical and experimental germination was found (Table III and Graph II).

TABLE III.

2,4-D concn. $\times 10^{-3}M$	0.45	0.68	0.91	1.13
Theoretical	82 ± 2	80 ± 3	75 ± 3	74 ± 6
Experimental	47 ± 8	35 ± 11	26 ± 1	23 ± 2

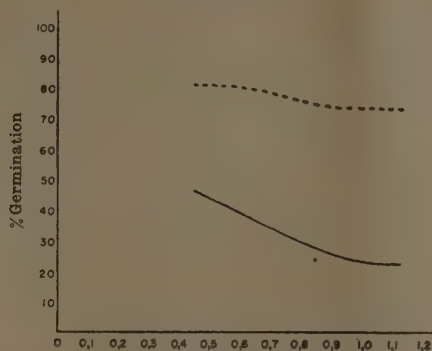
Coumarin and Thiourea

2,4-D - Concentration $\times 10^{-4}$

Graph I

Experiments with wheat: dotted lines theoretical, full lines experimental.

2,4-D and Cysteine

2,4-D Concentration $\times 10^{-4}$

Graph II

Experiments with Lettuce

2,4-D and Coumarin

A very marked synergistic effect of the two substances is noted. At a concentration of $0.51 \times 10^{-3} \text{M}$ coumarin and $2.3 \times 10^{-3} \text{M}$ 2,4-D a tenfold increase of inhibition of germination is observed (Table IV and Graph III).

2,4-D and Thiourea

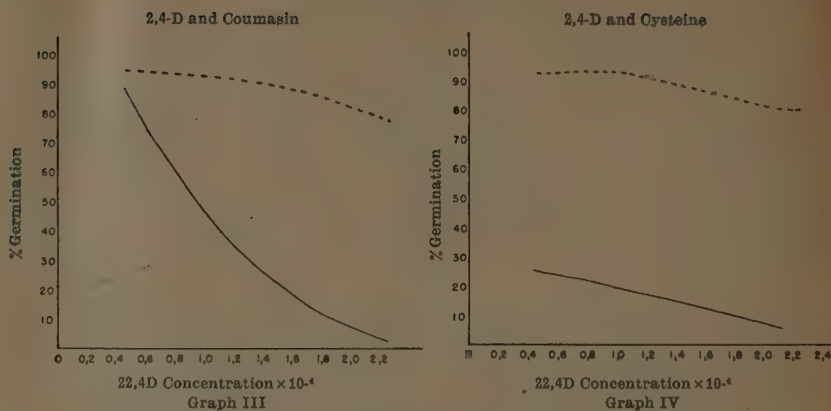
The thiourea concentration was $19.5 \times 10^{-3} \text{M}$. As far as the figures indicate there is a definite increase in germination as compared to the theoretically expected value, showing a stimulating effect of thiourea (Table V).

TABLE IV.
Coumarin concn. $0.51 \times 10^{-3} \text{M}$

2,4-D concn. $\times 10^{-4} \text{M}$	0.45	1.15	1.7	2.25
Theoretical	94	92	87	77
S.D.	3.5	4.5	5	7
Experimental	89	40	16	4
S.D.	2.5	38	14.5	6

TABLE V.

2,4-D concn. $\times 10^{-4} \text{M}$	2.25	4.5	6.75	9.0
Theoretical	75	75	56	37
S.D.	8.7	7.9	5.5	6
Experimental	89	83	67	60
S.D.	4	4.5	7.2	9.8



Experiments with lettuce: dotted lines theoretical, lower lines experimental.

TABLE VI.

2,4-D concn. $\times 10^{-4}M$	0.45	1.12	1.68	2.25
Theoretical	93.3 ± 7	92 ± 2	86 ± 2.2	81 ± 3.5
Experimental	26 ± 2.1	9 ± 2	13 ± 9.2	7 ± 5.2

TABLE VII.

Coumarin concn. $\times 10^{-3}M$	0.34	0.68	1.02	1.37
Theoretical	97 ± 1	86 ± 1	76 ± 1	53 ± 11
Experimental	84 ± 2	41 ± 5	19 ± 3	22 ± 11

2,4-D and Cysteine

At a constant cysteine concentration of $6.4 \times 10^{-3}M$ a very marked depression in the germination is observed (Table VI and Graph IV).

Coumarin and Cysteine

At a constant cysteine concentration of $6.4 \times 10^{-3}M$ a germination depression is ob-

served, which is, however, less pronounced than in the case of 2,4-D and cysteine (Table VII).

Coumarin and Thiourea

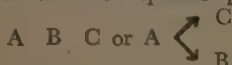
A very slight stimulation of germination at the higher coumarin concentrations is noted at a constant thiourea concentration of $19.5 \times 10^{-3}M$ (Table VIII).

TABLE VIII.

Coumarin concn. $\times 10^{-3}M$	0.34	0.68	1.02	1.37
Theoretical	97	94	82	66
S.D.	1	4.6	7.6	15.4
Experimental	97	95	90	79
S.D.	1	0.7	2.8	2.2

Discussion

As far as conclusions can be drawn from these experiments, these may be summarised as follows: 2,4-D and coumarin when acting together have a marked synergistic effect which greatly enhances their inhibitory action. This is particularly marked in the case of lettuce. This may be due to their acting on one and the same process or more probably due to their action on two separate processes such as



where the one inhibits $A \rightarrow B$ and the other $A \rightarrow C$ or $B \rightarrow C$.

Thiourea both in the case of wheat and of lettuce stimulates germination in conjunction with 2,4-D. Together with coumarin, however, wheat germination is depressed and lettuce slightly stimulated. This is further evidence for the view that different processes are involved in the action of 2,4-D and of coumarin.

Especially interesting is the effect of 2,4-D and cysteine. Firstly, whereas coumarin and cysteine show a limited enhancement of inhibition, 2,4-D and cysteine show a very pronounced similar effect, once more providing evidence for the view that two separate processes are involved. Even more remarkable is the fact that cysteine, which unlike the germination stimulant thiourea, does not effect germination at all, is so effective an inhibitor in conjunction with 2,4-D. In addition the effect observed directly opposes the view that 2,4-D acts on the -SH- containing enzymes. Were this the case then cysteine would be expected to act as a competitor for the inhibitor thus decreasing its effect. The cause for this may be either some form of activation of the systems affected by the inhibitor or it may be a simple permeability effect, the permeability to the inhibitor being increased.

The synergism of 2,4-D and coumarin already mentioned is of great practical interest also. Experiments on a more extensive scale are at present being carried

out to test how far this synergism operates when both the seeds and the seedlings of wheat, lettuce and tomatoes are sprayed with the two solutions in conjunction. Preliminary experiments have indicated that tomato seedlings are rapidly killed when the solution is applied to the roots. Seeds are also apparently prevented from germination when watered or sprayed with the solutions. This part of the work is being continued.

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THE ACTION OF ALLOXAN ON THE PROTEOLYTIC ACTIVITY OF HUMAN GASTRIC JUICE AND OF COMMERCIAL PEPSIN*

It was found by Purr¹ that alloxan inhibits the cleavage of gelatine by glycerol extracts of minced rat liver. Similar results were obtained by us with aqueous extracts of dry preparations of beef liver and beef kidneys. These extracts, tested at pH 4-5, were activated by cysteine and inactivated by alloxan. They were completely inactive at pH 2.

* Received March 1951

Freudenberg and Buchs² claim that human gastric juice contains, in addition to pepsin, a second protease, cathepsin, which is responsible for the relatively strong proteolytic activity of this juice towards milk protein at pH 4.7. In this connection, we have investigated the action of alloxan on the proteolytic activity of the gastric juice of five adults. In accordance with the findings of Freudenberg and Buchs we found that gelatine was cleaved by human gastric juice at pH 4-5 to an extent that amounted to approximately 60% of the cleavage obtained at pH 2. The pH range 4-5 is known to be optimal for the hydrolysis of gelatine by cathepsin of liver, spleen, kidney, and gastric mucosa³. We found, however, that the action of human gastric juice on gelatine at pH 4-5 was not affected at all by the addition of alloxan, either alone or in presence of cysteine.

Similar results were obtained with commercial pepsin. In accordance with the observations of Willstätter and Bamann⁴ we found a relatively good proteolytic action towards gelatine at pH 4-5 as compared with the same action at pH 2. But, as in the case of the gastric juice, this action of commercial pepsin at pH 4-5 was not inhibited by the addition of alloxan.

Typical results of our experiments are given in Tables I-IV.

TABLE I

Effect of alloxan on hydrolysis of gelatine by beef liver and beef kidney cathepsin.

Enzyme extracts were prepared by 4 hours incubation of liver or kidney powder⁵ with water (10 ml per g.) at 37°. The extracts were centrifuged and filtered. Cysteine-HCl (4 mg. per cc.) was added and the solution was kept at 30° for 30 minutes. Alloxan (8 mg. per cc.) was added to a part of the solution and both parts were kept at 30° for an additional hour. The increase in amino-N was measured in a manometric Van-Slyke apparatus. The pH was adjusted by adding citrate buffers and measured at the be-

ginning and at the end of the experiments by the aid of a Beckman pH-meter. All the experiments were carried out at 37°.

Reaction mixture	pH	Increase in amino-N after 48 hours (mg. x 1000) per 4 cc.
Enzyme* + cysteine 5 cc	4.7	183
Gelatine 2% 10 cc		
Buffer 10 cc		
Enzyme* + cysteine + alloxan 5 cc		
Gelatine 2% 10 cc	4.6	0
Buffer 10 cc		
Enzyme** + cysteine 5 cc		
Gelatine 2% 10 cc	4.7	240
Buffer 10 cc		
Enzyme** + cysteine + alloxan 5 cc		
Gelatine 2% 10 cc	4.9	7
Buffer 10 cc		

* Beef liver cathepsin. ** Beef kidney cathepsin.

TABLE II

Effect of alloxan added after addition of cysteine on hydrolysis of gelatine by gastric juice.

Gastric juice was taken in the morning in the usual way and filtered through glass wool. Cysteine-HCl and alloxan were added as described in Table I.

Reaction mixture	pH	Increase in amino-N after 96 hours (mg. x 1000) per 2 cc.
Gelatine 4% 2 cc		
Gastric juice + cysteine 2 cc	4.6	53
Buffer 2 cc		
Gelatine 4% 2 cc		
Gastric juice + cysteine + alloxan 2 cc	4.5	54
Buffer 2 cc		

TABLE III

Effect of varying pH and of alloxan and cysteine on hydrolysis of gelatine by gastric juice.

Reaction mixture	pH	Increase in amino-N after 96 hours (mg. x 1000) per 2 cc.	
Gelatine 4%	2 cc		
Gastric juice	2 cc	1.7	70
Buffer	2 cc		
Gelatine 4%	2 cc		
Gastric juice	2 cc	4.8	44
Buffer	2 cc		
Gelatine 4%	2 cc		
Gastric juice + alloxan	2 cc	4.5-4.6	45
Buffer	2 cc		
Gelatine 4%	2 cc		
Gastric juice + cysteine	2 cc	4.8	41
Buffer	2 cc		

TABLE IV

*Effect of alloxan on hydrolysis of gelatine by commercial pepsin**

Reaction mixture	pH	Increase in amino-N after 48 hours (mg. x 1000) per 4 cc.	
Gelatine 2%	10 cc		
Pepsin	5 cc	1.8	73
Buffer	10 cc		
Gelatine 2%	10 cc		
Pepsin	5 cc	4.8	33
Buffer	10 cc		
Gelatine 2%	10 cc		
Pepsin + cysteine	5 cc	4.9	36
Buffer	10 cc		
Gelatine 2%	10 cc		
Pepsin + cysteine + alloxan	5 cc	4.5-4.8	36
Buffer	10 cc		

* 3% solution of a B.D.H. product.

The above findings may be interpreted in one of the following ways. a) Gastric juice and commercial pepsin contain a cathepsin which, unlike the cathepsin of beef liver, rat liver and beef kidney, is not affected by alloxan. b) The cathepsin component of gastric juice and of commercial pepsin is accompanied by a natural activator so powerful that it cannot be overcome, even partially, by alloxan. (Such a possibility could eventually be proved by elimination of the activator either by dialysis or by oxidation). c) Gastric juice and commercial pepsin do not contain cathepsin at all and their proteolytic activity at pH 4-5 is a mere manifestation of a weakened action of pepsin.

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HEMOLYSIN OF *CL. BOTULINUM* TYPE A *

In assaying the toxin of *Cl. botulinum* type A by means of hemagglutination according to Lamanna¹, it was observed that the toxin causes hemolysis after prolonged incubation. All tubes which exhibited strong agglutination after 2 hours, showed hemolysis, when incubat-

*Received May 1951

ed at 34°C for 12 hours. Experience has shown that the end point of the hemolysis is much sharper than that of the hemagglutination, so that the former can be used advantageously for the assay of the toxin.

In this connection attention is drawn to the report of Prevot & Brygoo² that *Cl. botulinum* type D produces together with a true lethal toxin, a distinct hemolysin and a non-antigenic convulsant. It remains to be seen whether these multiple effects in type A cultures are due to a single molecular species or to distinct factors.

A detailed report will be published elsewhere.

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THE INFLUENCE OF X-RAY IRRADIATION ON THE SEVERITY OF INFECTION IN WHITE MICE, INFECTED WITH RICKETTSIA BURNETI***

It has recently been reported¹ that large doses of X-rays increase the susceptibility of white mice to infection with *R. Proxazeki*, the causative agent of epidemic typhus. It was thought to be of interest to determine whether this type of treatment

would also increase the susceptibility of white mice to *R. burneti*, since this effect would make possible large-scale chemotherapeutic trials as well as epidemiological experiments which are more costly and more difficult to perform with guinea-pigs. Groups of mice were irradiated and later were infected by various routes with materials containing viable *R. burneti*. After infection, the mice were kept under observation for a period of 21 days. The presence of rickettsial infection was confirmed by microscopic examination of smears prepared from the spleen and lungs of mice dying during this period.

Irradiation was carried out by means of a Picker 250 Deep Therapy Unit, operating at 200KV and 15MA through filters of 0.5 mm copper and 1 mm aluminium.

R. burneti was cultivated in the yolk sac of developing chick embryos. Suspensions of the yolk sac in saline were prepared and showed egg infecting titers of 10^{-6} to 10^{-7} per ml. These suspensions were used for the infection of mice.

The results of the experiments are summarized in Table I.

Sufficiently large doses of X-rays increased the severity of infection in white mice infected with *R. burneti*. The optimal dose of X-rays seems to be about 450R units, larger doses causing too high a death rate in uninfected controls and smaller doses resulting in lessened severity of infection.

Although the numbers of mice used in experiments with lyophilized material, and with infectious material suspended in water, are somewhat small, it would seem to be of epidemiological significance that the death rate in animals infected by mouth, using these materials, was at least as high as in animals infected by intraperitoneal injection or by intranasal instillation.

A detailed report will be published elsewhere.

* Received Sept. 1950.

** Aided by a grant from the National Foundation for Infantile Paralysis.

TABLE I.

X-ray dosage in Roentgens	Route of infection	Number of mice	Number of deaths	Deaths in %
—	I.P.	85	5	6
400	I.P.	10	4	40
400	—	10	0	0
450	I.P.	75	58	77
450	—	75	10	13
500	I.P.	60	41	70
500	—	30	13	43
—	*F	50	1	2
450	*F	30	4	13
500	*F	20	5	25
—	**F	10	3	30
450	**F	10	9	90
—	***D	10	0	0
450	***D	10	8	80
—	I.N.	40	11	28
450	I.N.	40	25	63
500	I.N.	14	6	43

I.P. — intraperitoneal injection.

F — feeding.

D — drinking.

I.N. — intranasal instillation.

* — white bread was allowed to absorb yolk sac suspension and was then fed to the mice.
Each animal received approximately 0.5 ml of yolk sac.

** — yolk sac harvested in sterile skimmed milk and lyophilized was mixed with dry food.
The mixture was fed to the animals on the basis of 0.5 ml of yolk sac suspension per animal.

*** — yolk sac was diluted approximately 1:100 in the drinking water furnished to the mice,
and 0.5 ml of yolk sac suspension allowed per animal.

The authors wish to thank Dr. A. Simons for making his X-ray apparatus available for their experiments, and Mrs. Goldie Elkis for her assistance in irradiating the animals.

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HOLOMETABOLIC DEVELOPMENT IN THE MALES OF COCCOIDEA *

Hitherto, students have hesitated to recognise the metamorphosis of the male *Coccoidea* (*Rhynchota*, *Phytophthires*) as holometaboly, in spite of the full agreement of their external development with that of the recognised holometabola. As they belong to a heterometabolic group of totally different phylogenetic development (the *Rhynchotoidea*), it was assumed that the one or two pupal stages intercalated between the mobile stages (larvae

* Received March 1951

and adult), and in the male series only, are but a superficial convergence, while the process of histolysis and the total reconstruction of the inner organs are less intensive or lacking. The last reviewer, Balachovsky¹, calls it premature, for the moment, to make too close a comparison between the metamorphosis of the male and that of the higher insects, and Weber² (1933 p. 569) classified the metamorphosis of the male *Coccoidea* with that of the *Thysanoptera* as neometabola, a subgroup of the heterometabola. He agrees, however, that conditions in the *Diaspididae* may hint at the way in which true holometaboly may have originated.

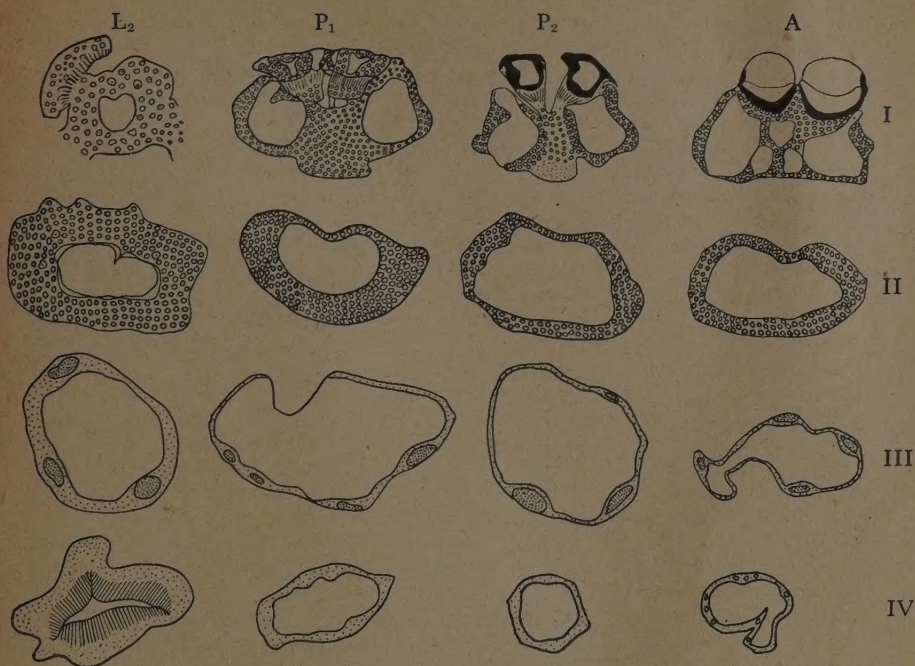
On the basis of internal anatomy, the present state of knowledge can be summarised as follows: Schmidt³ (1885 p. 169 ff.) in a comprehensive study on the metamorphosis of the male of *Aspidiotus hederae*, stated that in the prepupa the mouth musculature and the wax glands disappear suddenly. While the thoracic wing musculature of the male begins to show in the second larva, their insertions becoming conspicuous only in the pupa. The salivary glands disappear, but perhaps only in the pupa. The eye-lens is formed in the prepupa and progressively changes as the insect develops into adulthood. The shape of the testes changes suddenly in the prepupa, while the connection of the ductus ejaculatorius with the external genitalia appears to be made only in the pupa.

Berlese⁴ (1896 p. 206) has described the deviating exopterygotid development of the leg buds of *Mytilococcus beckii*. He has stated (1893 p. 145) that the larval central nervous system of *Pseudococcus citri*, which entirely persists in the neotenic female, undergoes a sudden change in the male prepupa and shows only minor and gradual changes during further development. Similar sudden changes in the inner anatomy of male *Coccoidea* are mentioned by him (1895 p. 244 f., 1896 p. 30, etc.). P. Suter⁵ (1932 p. 382) maintains that in *Mytilococcus ulmi* the change of the central nervous system occurs progressively only in the prepupa, which

however shows the two big pigment eye-spots immediately. Nel⁶ (1930 p. 432) states that in *Aonidiella aurantii* the prepupa shows diffuse eye-spots, which only in the pupa assume the definite areas of the adult eyes. In view of the statement of Schmidt that the lenses already develop in the prepupa, this seems to be a point of little consequence.

In our study of *Aspidiotus hederae* attention was paid to the changes of histological structures. It was found that, as in the true holometabola, great and rapid changes take place in the early prepupa with relatively few and gradual changes as the adult state is approached. This is very conspicuous in the ganglion supraoesophagale and the eye lobes as well as in the thoracic ganglion (fig. row 1 and 2). For the various parts of the intestinal tract, the same applies. In the oesophagus the spine like processi into the lumen of the larva disappear in the prepupa. In the midgut the thick larval epithelial cytoplasm is extended and reduced to less than its larval depth, so that the nuclei with the surrounding cytoplasm protrude into the lumen. The collapse of the midgut or other parts of the pupal or adult intestinal tract mentioned by Schmidt, was not observed. The lumen was always well established (fig. row 3). The very thick wall of the rectum with its four rectal papillae becomes thin-walled from the prepupa onwards with disappearance of the rectal papillae. In contrast to the larval rectum with its narrow lumen, the lumen is now considerable (fig. row 4). In the prepupa the vasa Malpighi lose the big, roundish excrements in their lumina, which are so characteristic for the larva.

All these sudden and considerable changes from the second larva towards the male prepupa show full agreement with the principle of holometaboly and we see no reason to separate it from that category. The same is obviously true of the *Thysanoptera* for which K.R. Muller⁷ (1928 p. 299) showed that a radical change and full replacement of the midgut epithelium of the prepupa has taken place, and



EXPLANATION OF FIGURES.

The Columnar series represent cross-sections of the second larva, prepupa, pupa and adult male stages of *Aspidotus hederæ* Vall.

Above: Ganglion supra-oesophagale with eye; second row: thoracic ganglion; third row: midgut; below: rectum.

that the intestinal musculature also undergoes full replacement.

We are unable to recognise any basic difference in the metamorphosis of the male *Coccoidea* and of the *Thysanoptera* from true holometaboly. The appearance of true holometaboly in phylogenetic lines, which usually have led only to heterometabolic development, shows that holometaboly has not originated in one phylogenetic line only, in the *Panorpoidea*, but that rudimentary attempts in its direction have occurred independently and repeatedly in other lines, too. This is the more interesting, as many modern students include the holometabolic *Coleoptera* in the phylogenetic line of the *Orthopteroidea*, another essentially heterometabolic group. Studies are yet to be made to determine

whether the exopterygism of the *Coccoidea* males is accidental or essential.

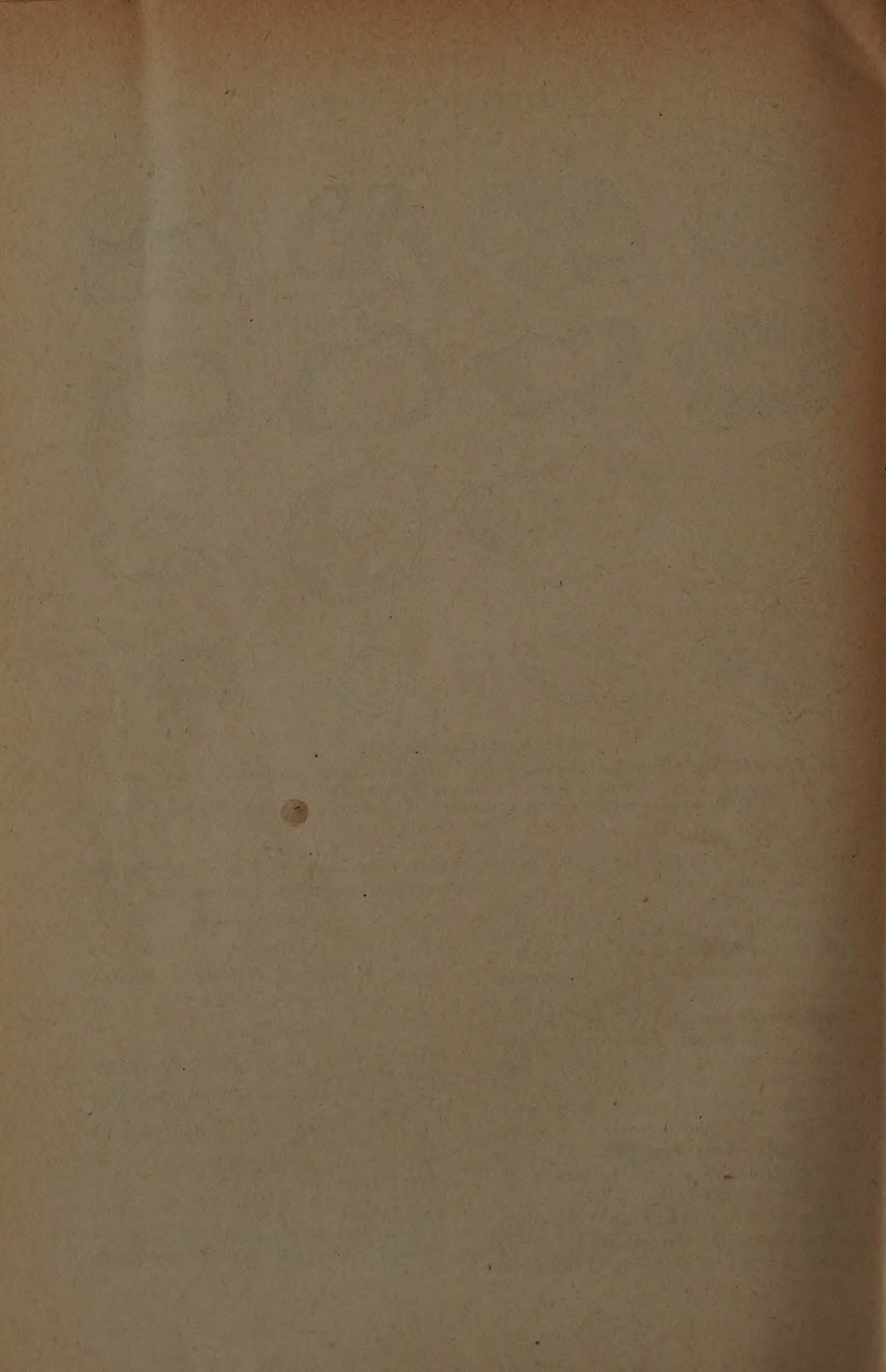
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